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Subject: LCP RI Report: Annotated Final Draft
Attachments: RIR070313(rem_inv_rpt)_(redline_final).pdf; Comment_Tracking_Table_(070313).pdf

Jon,

We are pleased to provide an annotated final draft of Volume I (Report Text) of the document titled "Remedial Investigation Report (RIR), LCP Chemicals, Inc. Superfund Site, Linden, New Jersey". A separate file containing the "Comment Tracking Table" is also presented that addresses the agency comments received from 2009 to date. These documents are provided for your final review of the RIR per your discussions with Mr. John Hoffman of Ashland.

Please note that the annotated draft RIR includes the accumulated edits that have been made in response to the various agency comments. The edits are identified with red colored text and strikethroughs. The edits are annotated with cross-references to the comment tracking table to facilitate your review by providing the context of the various changes.

Please contact John Hoffman or me with any questions or comments that you may have.

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Professional Registration in Specific States

~~draft~~ Remedial Investigation Report
LCP Chemicals, Inc. Superfund Site
Linden, New Jersey
Volume I of V
Report Text

Prepared for

ISP Environmental Services, Inc., Wayne, New Jersey

July 2013

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Prepared for
ISP Environmental Services, Inc.
1361 Alps Road
Wayne, New Jersey 07470

July 2013

Project Number: 135451.201

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LCP Chemicals, Inc. Superfund Site
Linden, New Jersey
Volume II of V
Appendices A through G

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Comment [PJT6]: Ditch Report

Executive Summary

The LCP Chemicals, Inc. Superfund Site (LCP site) Remedial Investigation (RI) is reported herein. The RI field investigation has been performed in two phases under the regulatory and technical oversight of the USEPA, with a further adjunct investigation of two off-site ditches located adjacent to the site. This report includes a comprehensive characterization of the nature and extent of contamination on the site in addition to assessments of risk to human health and the environment.

Comment [PJT7]: Ditch Report

Site History

The LCP site is a former chemical manufacturing plant located on an approximate 26 acre property. The site was developed in the early 1950s for the production of chlorine by the brine cell process (mercury cathode carbon anode) also known as the chlor-alkali process. Chlorine manufacturing operations commenced in 1955 and continued until the plant was shut down in 1985. Related operations, including a hydrogen gas processing plant and sodium hypochlorite manufacturing area were also located on the site. While the plant was initially developed and operated by GAF beginning in 1955, the facility was sold to LCP in 1972 and was expanded and operated by LCP until 1985. Activities continued on site (by LCP and others) until 2000.

Hanlin Group, Inc., d.b.a. LCP, filed a petition under Chapter 11 of the bankruptcy code in 1991 and liquidated all of its assets before April 1994 using the proceeds to pay creditors including the USEPA. The Linden, New Jersey property was abandoned by Hanlin Group pursuant to an order of the Bankruptcy court and ownership reverted back from the bankruptcy estate. Title to the property is currently listed as LCP-Chemicals New Jersey, a d.b.a. for Hanlin. Hanlin is a defunct corporate entity. The facility has remained abandoned since 2000.

The site was placed onto the National Priority List (NPL) in 1998. A voluntary Administrative Order was entered into by the USEPA and ISP-ESI in 1999 to perform a Remedial Investigation and Feasibility Study (RI/FS). ISP Environmental Services Inc. (ISP ESI) is currently the only potentially responsible party, among several, that has cooperated with USEPA to address the site.

The LCP site has a complex history of industrial ownership. The north-central and eastern portions of the property were owned and developed by various companies preceding GAF dating back to the 1880s. Other portions of the property were previously owned by E.I. duPont de Nemours and Central Railroad of New Jersey (now Conrail).

The entire area of the LCP site and nearly all of the surrounding area was historically tidal wetlands. It was necessary to raise the elevation prior to the historic development of these areas for industrial and other uses through the placement of anthropogenic ~~historic~~ fill. The filling of the property occurred during the prior ownership of the property, before the development of the LCP site in 1955. ~~The anthropogenic fill found on the LCP site meets the legal definition of "Historic Fill" contained in the New Jersey "Technical Requirements for Site Remediation" [N.J.A.C. 7:26E].~~

Comment [PJT8]: ES#1

Comment [PJT9]: ES#1

The site has been zoned for "heavy industrial use" and continues as such as do the surrounding properties. It is anticipated that the upland portion of the site could possibly be re developed into another industrial use, such as warehousing, transportation or electric power generation.

Contamination Sources

The RI results are summarized by the finding of the widespread presence of mercury in various environmental media as a result of manufacturing activities at the LCP site. Other contaminants potentially related to chlorine production are also found, including hexachlorobenzene (HCB), polychlorinated naphthalenes (PCNs), and polychlorinated dibenzo furans (PCDFs). Polychlorinated biphenyls (PCBs) are also a site-related constituent due their potential presence in electrical equipment on the site. Each of these other site-related constituents is present at levels much less than those of mercury. These other site-related contaminants are co-located with mercury; however the frequency and magnitude of exceedances of soil remediation standards is, respectively, less than that of mercury.

Comment [PJT10]: ES#2

Contamination is also present as a result of the prior placement of ~~historic~~ anthropogenic fill materials. Contaminants that are ubiquitous in fill materials include metals/metalloids (e.g., lead, chromium, and arsenic), and polycyclic aromatic hydrocarbons (PAHs) as a result of the common practice of using combustion residues (e.g., coal ash and slag) as fill. Other contaminants in the ~~historic~~ anthropogenic fill are consistent with sources of industrial fill from neighboring properties (e.g., duPont, GAF) and include arsenic and chlorobenzenes. Other various chemicals, including dioxins, are also found from regional sources such as air deposition and sediment transport.

Comment [PJT11]: ES#1

Comment [PJT12]: ES#1

Contamination Conditions

The surficial fill at the LCP site is impacted primarily with mercury which is widely distributed throughout the site. This contamination includes some visual observations of elemental mercury in areas surrounding the main production buildings. However, the horizontal and vertical migration of mercury and other site-related constituents is relatively limited and the underlying ~~natural~~ soils contain concentrations that are lower than those in the overlying ~~are impacted to a much lesser degree than the~~ fill.

Comment [PJT13]: ES#4

Groundwater contamination at the site results from the dissolution of the various contaminants from site soils (both LCP related and fill related). Groundwater contamination, however, shows minimal migration either horizontally or laterally and is not moving off site to any significant extent. In addition, groundwater at the site is non-potable as the result of naturally occurring saline conditions. Since the groundwater is saline, alternative groundwater quality criteria (AGWQC) are relevant at the site, and site-specific AGWQC have been developed.

Sediments and low marsh soils in South Branch Creek (an on-site, man-made tidal ditch) are contaminated with mercury and other constituents, especially in the "upstream" areas. The contamination decreases with distance from the manufacturing area of the site and is essentially at background levels where South Branch Creek meets the Arthur Kill. ~~The sediment contamination is due to historic inputs from the LCP site and~~ Similar contaminated sediment conditions are observed in the Northern Off-Site Ditch Sediments, albeit at lower concentrations than South Branch Creek. The sediment contamination in South Branch Creek and the Northern Off-Site Ditch ~~is not~~ do not appear to be due to ongoing sources. Biological specimens (fish and crabs) collected in South Branch Creek contain elevated concentrations of mercury and other constituents compared with those collected in a nearby area.

Comment [PJT14]: Ditch Report

Comment [PJT15]: ES#7

~~Human exposures to site media are currently limited since the site is unoccupied and fenced. Cancer risks for future hypothetical construction workers via dermal contact with groundwater exceeded the low end of USEPA acceptable risk levels due to furans. Future use potential non-cancer risk estimates to site occupants for direct exposure to soil and inhalation of vapors in indoor air exceeded the USEPA benchmark due primarily to mercury. All other cancer and non-cancer risks were within acceptable levels.~~

Comment [PJT16]: Updated HHRA/BERA

~~Several contaminants in South Branch Creek sediment have the potential to result in adverse ecological effects to benthic macroinvertebrates. Potential ecological risks were also identified for mammalian insectivores, but ecological exposure to terrestrial soil is not considered a significant pathway given the limited habitat. Potential ecological risks for upper trophic level receptors feeding in South Branch Creek were in the borderline acceptable range.~~

~~In summary, while site soils and sediments are contaminated with mercury and other site related constituents, groundwater is relatively unimpacted as a result of the site. This is largely due to the fact that mercury is present in relatively insoluble, immobile forms. Net transport of mercury outward from the site to the Arthur Kill via flow of suspended particulates in surface water also appears to be limited, yet finite. Contaminant movement from sediment into biota is the environmentally significant migration pathway.~~

Comment [PJT17]: ES#9

The Human Health Risk Assessment (HHRA) indicated that exposure to soil and soil vapor by future commercial/industrial workers, site-specific workers, and construction/utility workers may result in adverse non-cancer effects; exposure to soil by future commercial/industrial workers may also result in adverse cancer effects. Dermal contact with groundwater by construction/utility workers has the potential to result in adverse non-cancer effects. Potential non-cancer hazards in soil and soil vapor were driven by mercury; potential non-cancer hazards in groundwater were driven by furans and manganese. No unacceptable cancer or non-cancer risks were identified for current/future trespassers exposed to sediment/bank soil in South Branch Creek. Hypothetical use of groundwater for potable purposes was also evaluated to support remedial decision-making and risk management; the HHRA indicated future potable use of groundwater by commercial/industrial workers may result in adverse cancer and non-cancer effects.

The Baseline Ecological Risk Assessment (BERA) indicated that contaminants in South Branch Creek sediment, primarily arsenic, barium, and mercury, have the potential to result in adverse ecological effects to benthic macroinvertebrates and sediment-probing birds. Potential ecological risks were also identified for terrestrial mammals (insectivores) and birds (invertivores and, to a lesser extent, carnivores) potentially exposed to contaminants in upland soil, driven primarily by mercury and hexachlorobenzene. However, the former facility offers limited ecological habitat for these receptors as the majority of the Site is paved or occupied by structures.

Section 1

Introduction

This report presents the findings of a multi-phased Remedial Investigation (RI) performed at the LCP Chemicals, Inc. Superfund Site located in Linden, New Jersey. The initial phase (Phase I) of the RI was performed in 2001-2002 and was reported in the document titled, "Site Characterization Summary Report, LCP Chemicals Superfund Site, Linden, New Jersey", (Brown and Caldwell, August 2002). The Phase II RI field investigation was performed during 2006-2007 and the data was reported in the document titled, "Phase II Site Characterization Summary Report, LCP Chemicals Superfund Site, Linden, New Jersey, (Brown and Caldwell, September 2007). In addition an adjunct investigation to the RI was performed in 2011 on the two off-site ditches, in response to EPA comments on the draft RI Report (Brown and Caldwell, September 2008). The RI Report, presented herein, provides a comprehensive presentation and analysis of the RI data.

Comment [PJT18]: Ditch Report

1.1 Authority

The site was placed onto the National Priority List (NPL) in 1998. On May 13, 1999, Administrative Order No. II CERCLA 02 99 2015 (hereinafter referred to as the Order) was entered into voluntarily by the United States Environmental Protection Agency (USEPA) and ISP Environmental Services Inc. (ISP-ESI). ISP ESI is currently the only potentially responsible party, among several, that has cooperated with USEPA to address the site. The stated purpose of the Order was to:

"(a)... conduct a remedial investigation ("RI") to determine the nature and extent of contamination and any threat to the public health, welfare, or the environment caused by the release or threatened release of hazardous substances, pollutants or contaminants at or from the Site; (b) to determine and evaluate alternatives, through the conduct of a feasibility study ("FS"), to remediate said release or threatened release of hazardous substances, pollutants, or contaminants; (c) to provide for the reimbursement to EPA of response and oversight costs incurred by EPA with respect to the Site; and (d) to provide for reimbursement to EPA of response costs incurred by EPA at the Site prior to the effective date of this Consent Order."

In accordance with the provisions of Section VII.25.H of the Order, the RI Report is hereby submitted. The RI report provides an analysis of the horizontal and vertical extent of mercury and other site constituents at the site in the various site media. The RI field investigation and reporting were performed by Brown and Caldwell from 2001 through 2008 under contract to and on behalf of ISP-ESI. The scope of the initial phase of the RI field investigation was performed in accordance with the USEPA-approved Work Plan documents described in Section 1.4.1. The technical objectives and scope of the Phase II RI field investigation was performed in accordance with the USEPA-approved Work Plan documents described in Section 1.4.2.

Baseline Human Health Risk Assessment (BHHRA) and Baseline Ecological Risk Assessment (BERA) have been performed in accordance with a pending amendment to the Administrative Order Amendment. The BHHRA and BERA were performed by Geosyntec Consultants Inc. under contract to ISP-ESI and are summarized, herein. The full text of BHHRA and BERA reports are provided as Appendices P and Q, respectively.

1.2 Site Description

The LCP Chemicals, Inc. Superfund Site (hereinafter referred to as the LCP site) is located in the Tremley Point section of the City of Linden, Union County, New Jersey. The site is located along the western shore of the Arthur Kill and east of the New Jersey Turnpike as shown on Figures 1-1 and 1-2. It is accessed from the Road to Grasselli, which is reached from Linden via South Wood Avenue and Tremley Point Road. The coordinates of the approximate center of the site are Latitude 40.60832° and Longitude -74.21163°.

The site was formerly an industrial complex with chemical manufacturing operations. A mercury-cell, chlorine production (chlor-alkali) facility was operated at the site from 1955, until cessation of manufacturing operations in 1985, and included a mercury-cell chlorine process area, hydrogen gas processing plant, and sodium hypochlorite manufacturing area, as shown on Figure 1-3. The site was also used as a terminal for products produced at other facilities and various other industrial operations. In addition, a variety of tenants operated on site until the site was closed in August 1994.

The area surrounding the LCP site was historically developed for heavy industrial use, much of which is currently inactive and/or decommissioned. Primary current, active land use in the area is bulk storage and transport of petroleum products and aggregates.

Tidal wetlands are known to have existed historically in the area of the site. The placement of anthropogenic fill to raise the grade for industrial development is known to have occurred starting in the 1880s along the margins of the Arthur Kill. ~~The anthropogenic fill found on the LCP site and the site vicinity meets the definition of "Historic Fill" contained in the New Jersey "Technical Requirements for Site Remediation" [N.J.A.C. 7:26E-1.8] and has been mapped as "Historic Fill" by NJDEP. This is described in additional detail in Section 2.~~

Comment [PJT19]: ES#1

1.3 Site History

1.3.1 Property Ownership

The real property parcels on which the LCP Chemicals, Inc. Superfund Site is located include City of Linden Block No. 587, Lots No. 3.01, 3.02, and 3.03. The land has a long and complex history of industrial use and property ownership. This ownership history has been researched by Keller & Kirkpatrick (2008) based on a detailed evaluation and reconstruction of the areas represented by various historic deeds that are available from public records from approximately 1909 to the present. Information regarding various property transfers and easements is presented on a series of maps by Keller & Kirkpatrick (Appendix A) and is summarized on Table 1-1. A description of the historic land ownership and easements is described on the basis of this research and on other available information.

1.3.1.1 Historic Land Ownership

The north central portion of the LCP site had a long history of industrial ownership starting in about 1880 with the Standard Chemical Works that was purchased by the Grasselli Chemical Company in 1889. Around 1924, the Grasselli Dyestuff Corporation, which is reported to have been a joint venture of Grasselli Chemical and Bayer AG, was incorporated under the laws of the State of Delaware.

The Grasselli Chemical Company transferred a number of large parcels to the Grasselli Dyestuff Company on October 20, 1928 which included, in part, the northern portion of what became the LCP property. Parallel property transfer records indicate duPont purchased the property in 1928. The property transfer record indicates this same area was transferred by Grasselli Chemical Company to E.I. duPont de Nemours and Company (duPont) on November 30, 1928. In addition, a strip of property extending to the Arthur Kill east of the tracks was also transferred to Grasselli Dyestuff Company that would later be used for relocation of South Branch Creek.

Grasselli Dyestuff Corporation changed its name to General Aniline Works, Inc. on February 27, 1929. The company then changed its name to General Aniline & Film Corporation on October 30, 1939 and merged into American I.G. Chemical Corporation on October 31, 1939[1].

In 1942, the United States Justice Department seized American I.G. Chemical Corporation as a war asset. While under government control, the General Aniline & Film Corporation completed construction of a chlor-alkali (chlorine manufacturing) plant on the LCP site in 1955. In 1965 the U.S. Government sold the ownership of General Aniline & Film Corporation in a public stock offering. General Aniline & Film Corporation changed its name to GAF Corporation on April 24, 1968.

Other parcels in what became the LCP property were acquired separately. The central portion of the LCP property located west of the railroad tracks was owned by E.I. duPont de Nemours and Company prior to 1949 and transferred to General Aniline & Film Company in 1949. The southern portion of the LCP property located west of the railroad tracks was transferred from Central Railroad Company of New Jersey to General Aniline & Film Company in 1958. A narrow strip of land along what is now the current southern property line and extending to the extreme eastern tip was transferred from Central Railroad Company of New Jersey to General Aniline & Film Company in 1967.

GAF Corporation sold the LCP Site which included the chlor-alkali facility to Linden Chlorine Products, Inc. of Edison, New Jersey on August 24, 1972. LCP Chemicals and Plastics, Inc. conveyed its property to LCP Chemicals-New Jersey, Inc. on December 14, 1979. At some point, the company became known as LCP Chemicals, Inc., a division of the Hanlin Group, Inc.

1.3.1.2 Easements

Numerous easements have been established at the LCP site. These easements include various rights of way for physical access by road and rail to the LCP site, use of utility poles and other utilities, use of the flume and outfall ditch for wastewater drainage, easements for numerous underground and overhead utility lines not specifically related to the LCP site including a historic sanitary sewer trunk line; gas and petroleum transmission lines; water lines; electric lines, access to leaseholds within the LCP site property; and access to other neighboring properties. These easements are listed on Table 1-1.

1.3.1.3 Site Operation

GAF began the chlorine operation at the LCP site in 1955. By 1956, the core of the buildings required for the chlorine productions were present, including Buildings 220 and 230. GAF had stopped operation of the chlor-alkali manufacturing facility in 1971. Linden Chlorine Products, Inc., which was founded in 1972, purchased the site from GAF and subsequently resumed operation of the plant. Another mercury cell building (Building 240) and other site buildings were added by LCP in the early 1970s.

As of 1975, Linden Chlorine Products, Inc. reported that it owned no other manufacturing facilities and that only three products were produced – chlorine, sodium hydroxide, and hydrogen. By the early 1980's, the company had acquired additional chlor-alkali manufacturing facilities, including sites in Syracuse, New York, Moundsville, West Virginia, and Brunswick, Georgia.

Portions of the LCP site were leased to other companies for the operation of other related manufacturing operations at the site. In 1957, part of the property to the west, was leased to Union Carbide Corporation (UCC) to be used as a hydrogen plant utilizing the by-products of the chlorine plant and is known as the Linden Division hydrogen plant. UCC operated its plant through 1990. Kuehne Chemicals, Inc. leased the northern portion of the property in 1972 and opened a sodium hypochlorite manufacturing plant, which also distributed and sold chlorine.

[1] The merger into American I.G. Chemical Corporation in 1939 is reported in the deed research by Keller & Kirkpatrick. Other records suggest that ownership by American I.G. Chemical Corporation may have occurred in approximately 1928 or 1929.

The ownership of the Linden Chlorine Products, Inc. facility became LCP Chemicals-New Jersey, Inc., a subsidiary of Linden Chemicals & Plastics, Inc. The chlor-alkali manufacturing operations had ceased by 1985 and the facility was used as a terminal for products produced at other locations.

Hanlin Group, Inc., d.b.a. LCP, filed a petition under Chapter 11 of the bankruptcy code in 1991 and liquidated all of its assets before April 1994 using the proceeds to pay creditors including the USEPA. The Linden, New Jersey property was abandoned by Hanlin Group pursuant to an order of the Bankruptcy court and ownership reverted back from the bankruptcy estate. Title to the property is currently is listed as LCP-Chemicals New Jersey, a d.b.a. name for Hanlin. Hanlin was formerly incorporated in New Jersey but is now a defunct corporate entity.

In August 1994, the EPA conducted a site visit and confirmed that the chlorine process buildings were decommissioned, the facility was no longer functional and that the site was vacated by LCP employees. Active Water Jet Inc., a pipe cleaning company, who was a tenant at the site since about the early 1990s, remained onsite until 2000. The facility has remained abandoned ever since.

1.3.2 Operations and Development

The text in this section has been adapted from the document titled "Work Plan, Remedial Investigation and Feasibility Study" (URS, October 6, 2000) and updated with information that has been obtained from other available sources. Much of the historic information presented, herein, is compiled from documents dating back to 1975 and earlier. Within these documents there are some contradictions concerning the past operations of the site. This problem is compounded by the fact that much of LCP Chemicals, Inc.'s records were lost or destroyed sometime in the 1980s (Eder, September 1993).

At the time of LCP Chemicals, Inc.'s mercury cell chlorine production, there were three main operating centers at the site; the mercury cell chlorine process area, the hydrogen gas processing plant, and the sodium hypochlorite manufacturing area. Materials needed for processing were shipped in by barge, rail, or by truck. Storage and distribution of chlorine and its related products (including methylene chloride and potassium hydroxide) occurred on this site throughout its history. The manufacturing operations were subject to periodic shutdowns due to changes in market demands for chlorine production. The processes by which the chlorine and its by-products were created are described in the section below.

1.3.2.1 Mercury Cell Chlorine Process Area

The mercury cell was an industrial system that split common salt molecules (NaCl) to produce chlorine gas. A typical mercury cell process used electrolysis to split the salt solution. An electric current was passed through the salt solution (brine) between a graphite anode and a mercury cathode (Figure 1-4) to produce chlorine gas and sodium. The sodium dissolved into the mercury and the sodium-mercury mixture was made to react with water to produce sodium hydroxide and hydrogen gas. All of the material from this process, including the spent brine, hydrogen gas and sodium hydroxide, contained residual amounts of mercury. The mercury was separated from the resulting chlorine and hydrogen gas and sodium hydroxide which were packaged for sale for additional processing and/or for distribution.

The raw materials used in the chlorine production process were salt, water, mercury, and electric power. Documentation of LCP Chemicals, Inc.'s procedure for the handling and storage of chemicals is not available. Rock salt or evaporated salt, which was utilized later, was transported to the site by rail. It was stored in salt silos located by Building 233 (Figure 1-3) and fed to the adjacent saturators to create brine. The brine was treated and filtered in a brine treatment tank in Building 233. To treat the brine, sodium hydroxide, sodium carbonate, and barium chloride were added to precipitate impurities in the solution, such as calcium carbonate, sulfates, and hydroxides. The residual material is known as brine purification mud or "brine sludge". In the mid 1960s, a surface impoundment, the brine sludge lagoon, was constructed and used to dispose the brine sludge and process wastewater. The sludge was mixed

with brine and the resulting slurry was pumped to the brine sludge lagoon through overhead pipes. The supernatant, or liquid content of the brine sludge lagoon, was pumped back to the brine purification tank for recycling and for redistribution either to the mercury cells or for the slurry usage. Documentation of the disposal practices for the brine sludge before the construction of the sludge lagoon is not available.

After pre-treatment of the brine, it was piped to the mercury cells in Building 230 and Building 240 to produce gaseous chlorine and a mercury sodium mixture through electrolysis. Once the chlorine was cooled, dried (i.e., water vapor removal) with sulfuric acid, and liquefied in Building 233, it was stored in 100 ton vessels. The used brine was recycled to the treatment tank in Building 233 for re saturation and to repeat the process.

The mercury-sodium mixture was then piped to denuders, or strippers, where it was hydrolyzed to form elemental mercury, a sodium hydroxide solution and gaseous hydrogen. The recovered mercury was returned to the mercury cells. The sodium-hydroxide solution was filtered and stored in above ground storage tanks at the northeast corner of the facility. The hydrogen gas was also filtered by way of a commercial "Purasiv" unit south of Building 231. From there it was piped to the hydrogen facility where it was packaged and distributed by Union Carbide (Linde Division). Occasionally, the hydrogen gas was mixed with water and chlorine to form hydrochloric acid in both gaseous and liquid form. The hydrochloric acid was then stored in tanks near Building 231. In 1985, LCP Chemicals stopped the mercury cell process, thus brine sludge production was also stopped.

Between 1985 and 1994, the site was used as a transfer terminal for products made at other Hanlin Group Facilities. The Hanlin products were shipped to the site via rail or truck and stored in above ground storage tanks. From there they were repackaged and distributed. The products were potassium hydroxide, sodium hydroxide, hydrochloric acid and methylene chloride. Aerial photographs of the facility during full operation in 1966-67 (Building 240 not constructed yet) and shortly after shut down of the mercury cell process are shown on Figures 1-5 and 1-6, respectively.

1.3.2.2 Linde Division Hydrogen Plant

The hydrogen plant was operated by the Linde Division unit of Union Carbide Corporation (Linde) which occupied a 2.1-acre leasehold on the western portion of the site (Figure 1-3) interconnected to the mercury cell process area. The Linde Division hydrogen plant started operation in 1957 and ceased operation in 1990. Hydrogen was supplied from the mercury cells to the plant via overhead pipes. The gas was purified by UCC to remove additional residual mercury (reportedly, at least five pounds of mercury was removed from the gas stream by Linde daily), stored, compressed, and shipped by trailer. Union Carbide, in their 104(e) response claims that one disposal method for the Linde waste mercury was to give it to employees for resale. In 1980, the hydrogen plant stopped using the hydrogen from the chlorine plant, and began to package liquid cryogenic hydrogen that was shipped in from outside sources.

In 1988, in preparation for a new tenant, UCC had the building interior and the hydrogen compressors decontaminated for mercury (IT, April 22, 1988). IT reportedly recovered 30 pounds of free mercury from one compressor and its associated piping.

In May 1990, the Linde Division plant ceased operations after the UCC lease with LCP expired. This triggered the NJDEP's Environmental Cleanup Responsibility Act (ECRA, now known as ISRA). Due to several areas of concern unrelated to the chlorine manufacturing process (i.e., former underground storage tanks, sumps, septic tanks, etc.), ISRA required that a soil and groundwater investigation be conducted within the boundaries of the site. The required investigation and its cleanup took place in the early 1990s. The NJDEP granted a No Further Action (NFA) declaration for the hydrogen facility on June 20, 1995 for soils only. To our knowledge, Praxair (successor to UCC) has had engineering controls on the leasehold.

The Linde Division facility was last used in October 1994 by Liquid Carbonic Corporation. Liquid Carbonic Corporation was later purchased by Praxair, Inc. Liquid Carbonic rented the Linde Division site from LCP Chemicals, Inc., and used it for office space and as a parking area for truck trailers.

1.3.2.3 Hypochlorite Facility

Kuehne Chemical, Inc., leased Lot Nos. 3.02, 3.03 and the northern part of Lot 3.01 from LCP Chemicals, Inc. and started a sodium hypochlorite manufacturing process. The processing area was located to the north of Building 220 and between Avenue C and D and consisted of above ground storage tanks, loading areas and support buildings (Figure 1-3). The manufacturing plant received its raw materials, chlorine and sodium hydroxide, from the LCP chlorine plant via overhead pipes. The raw material were utilized by Kuehne to produce sodium hypochlorite (bleach). Chlorine, sodium hydroxide, hydrochloric acid, and sodium hypochlorite were also stored and distributed by Kuehne. Kuehne Chemical Inc. had vacated the site by February 1981. It is likely Kuehne mercury waste was disposed of along with the LCP mercury waste.

1.3.2.4 Other Operators

Conrail (successor to Central Railroad of New Jersey) constructed and operated a railroad line and railroad yard across the property as described in Section 2.1.1 and as shown on Figure 2-8.

Active Water Jet operated a pipe and tank washing operation on the property from 1990 until 2000. Active Water Jet cleaned, with water blasting, contaminated tanks, filters, pipes, condensers and similar items. Its offices were located in building 220.

Caleb Brett leased a portion of the property from 1988 to 1995; they are known to have stored petroleum crude oil, No. 6 fuel oil, kerosene, asphalt products, pot ash, caustic soda, alcohol, and ketones at the site.

Microcell Technologies leased building 231 from 1987 until 2000 and operated a pilot plant that produced small glass spheres.

1.4 RI Site Investigation

The work plan documents and the technical objectives for each of the RI field investigations are described below.

1.4.1 Phase I RI

Phase I RI Work Plan Documents

The Phase I RI was performed during 2001 and 2002 in accordance with the following USEPA-approved documents:

1. "Work Plan, Remedial Investigation and Feasibility Study" (URS, October 6, 2000).
2. "Final Sampling and Analysis Plan, Field Operations Plan, Part I, Draft Sampling and Analysis Plan" (URS, April 12, 2001), hereinafter referred to as the FOP.
3. "Quality Assurance Project Plan, Field Operations Plan, Part II, Draft Sampling and Analysis Plan" (URS, February 12, 2001), hereinafter referred to as the QAPP.
4. "Addendum No. 1, Field Operations Plan for the LCP Chemicals, Inc. Superfund Site, Cased Deep Borings," (Brown and Caldwell, October 12, 2001).
5. "Addendum No. 2, Field Operations Plan for the LCP Chemicals, Inc. Superfund Site, Subsurface Utility Clearance," (Brown and Caldwell, November, 2001).
6. "Addendum No. 3, Field Operations Plan for the LCP Chemicals, Inc. Superfund Site, Sampling Beneath Buildings 230 and 240" (Brown and Caldwell, March 2002).

Agency approval of these Phase I RI Work Plan documents was provided in letters from USEPA in 2001 and 2002.

Comment [PJT20]: SC#1

Phase I RI Objectives

The objectives of the Phase I RI were stated in Section 2 of the "Final Sampling and Analysis Plan, Field Operations Plan, Part I, Draft Sampling and Analysis Plan" (URS, April 12, 2001):

- Determine the nature and extent of contamination in the soil, groundwater, surface water, and sediment.
- Evaluate stratigraphy on a site-wide basis - confirm the distribution of the Tidal Marsh Deposit and evaluate its effectiveness as a confining layer.
- Define the hydrogeology on a site-wide basis - confirm groundwater gradients, flow directions, and aquifer properties (e.g., hydraulic conductivity, transmissivity, etc.) to predict the direction and flow rate of groundwater contaminant migration.
- Evaluate tidal effects on groundwater and groundwater flow direction.
- Evaluate the potential ecological resources of, and impacts to, South Branch Creek.
- Characterize ~~historic~~ anthropogenic fill at the site.
- Develop a conceptual site model.
- Determine risks posed to human health and environment.

Comment [PJT21]: ES#1

The results of the Phase I RI field investigation were presented in the document titled, "Site Characterization Summary Report (SCSR), LCP Chemicals Superfund Site, Linden, New Jersey", (Brown and Caldwell, August 2002).

1.4.2 Phase II RI

Phase II RI Work Plan Documents

The Phase II RI was performed from August 2006 through June 2007 in accordance with the following 14 USEPA-approved documents:

1. "Work Plan, Remedial Investigation and Feasibility Study" (URS, October 6, 2000).
2. "Final Sampling and Analysis Plan, Field Operations Plan, Part I, Draft Sampling and Analysis Plan" (URS, April 12, 2001), hereinafter referred to as the FOP.
3. "Quality Assurance Project Plan, Field Operations Plan, Part II, Draft Sampling and Analysis Plan" (URS, February 12, 2001), hereinafter referred to as the QAPP.
4. "Addendum No. 1 (Soil and Groundwater) Work Plan: Phase II Remedial Investigation, LCP Chemicals, Inc. Superfund Site", (Brown and Caldwell, July 2004, Revised April 2006, Revised October 2006).
5. "Addendum No. 2 (South Branch Creek & Ecological Issues) Work Plan: Phase II Remedial Investigation, LCP Chemicals, Inc. Superfund Site", (Brown and Caldwell, July 2004, Revised August 2006, Revised October 2006).
6. "Addendum No. 1, Field Operations Plan for the LCP Chemicals, Inc. Superfund Site, Cased Deep Borings," (Brown and Caldwell, October 12, 2001).
7. "Addendum No. 2, Field Operations Plan for the LCP Chemicals, Inc. Superfund Site, Subsurface Utility Clearance," (Brown and Caldwell, November, 2001).
8. "Addendum No. 3, Field Operations Plan for the LCP Chemicals, Inc. Superfund Site, Sampling Beneath Buildings 230 and 240" (Brown and Caldwell, March 2002).

9. "Addendum No. 4, Field Operations Plan, LCP Chemicals, Inc. Superfund Site (Bedrock Monitoring Wells, Soil Vapor Testing, Groundwater Sampling)", (Brown and Caldwell, April 2006, Revised October 2006).
10. "Addendum No. 5, Field Operations Plan for the LCP Chemicals, Inc. Superfund Site, Ecological Sampling", (Brown and Caldwell, August 2006, Revised October 2006).
11. "QAPP Addendum for South Branch Creek Sampling," (Brown and Caldwell, August 2006, Revised October 2006).
12. "Supplemental Work Plan: Sediment Toxicity Testing (South Branch Creek), Phase II Remedial Investigation LCP Chemicals, Inc. Superfund Site," (Brown and Caldwell, September 2006, Revised October 2006).
13. "Interim Ecological Risk Assessment Problem Formulation," (Brown and Caldwell, Revised October 2006).
14. "Health and Safety Plan For Phase II Remedial Investigation at the LCP Chemicals, Inc. Superfund Site," (Brown and Caldwell, September 2006).

Agency approval of these Phase II RI Work Plan documents was provided in the following:

- Letter from Ms. Carole Petersen of USEPA dated September 13, 2006 referenced: "Conditional Approvals for Addendum No. 2 (South Branch Creek and Ecological Issues) Work Plan: Phase II Remedial Investigation, LCP Chemicals, Inc. Superfund Site (Revised July 2006); and Addendum No. 5 Field Operations Plan LCP Chemicals, Inc. Superfund Site (Ecological Sampling) (August 2006)."
- Letter from Ms. Carole Petersen of USEPA dated October 5, 2006 referenced: "Conditional Approvals for Addendum No. 1 (Soil and Groundwater) Work Plan: Phase II Remedial Investigation, LCP Chemicals, Inc. Superfund Site (April 2006) and Addendum No. 4 Field Operations Plan, LCP Chemicals Inc. Superfund Site (Bedrock Monitoring Wells, Soil Vapor Testing, Groundwater Sampling) (April 2006)."
- Submittal of revised Phase II Work Plan documents to USEPA by October 13, 2006 in accordance with the conditions set forth in the conditional approval letters.

Phase II RI Objectives

The Phase II RI Work Plan included an approach and methodology to address the following technical objectives:

- Additional delineation of surficial and shallow soils in the western area of the site through the installation and testing of soil from a number of borings.
- Characterization of deep soils through the installation and testing of a number of borings to determine the vertical extent of contamination identified in the shallow soils.
- Characterization of soil quality within the glacial till beneath Building Nos. 230 and 240.
- Determination of the presence of methyl mercury in soil from a number of shallow and deep soil samples obtained in various areas of the site.
- Determination of the specific form of mercury in a number of surficial soil samples including mercuric (Hg+2), mercurous (Hg2+2), and methyl (CH3Hg+).
- Characterization of surficial soil quality near storage tanks remaining at the site that may have had potential releases to the environment.
- Determination of groundwater quality in the bedrock water-bearing zone.

- Additional characterization of groundwater quality in the overburden water-bearing zone through the collection of a second complete round of monitoring well samples, including the use of "ultra-clean" sample collection and handling techniques for mercury.
- Determination of the groundwater flow characteristics in the bedrock water-bearing zone.
- Additional characterization of groundwater flow conditions in the overburden water-bearing zone.
- Determination of the in-place hydraulic conductivity of the unconsolidated and consolidated geologic material screened by the newly installed monitoring wells.
- Determination of the presence of methyl mercury in groundwater from a number of overburden and bedrock groundwater samples obtained in various areas of the site.
- Characterization of soil vapor to address the potential vapor intrusion pathway to future building structures at the site.
- Current wetland delineation and jurisdictional determination.
- Additional delineation of selected constituents in sediment and surface water in South Branch Creek as well as in the confluence area of South Branch Creek and Arthur Kill to address ecological concerns.
- Evaluation of the bioavailability of mercury in the surface water and sediment within South Branch Creek. This includes a determination of the ratio of methyl mercury to total mercury.
- Determination of the influence of mercury speciation and sediment chemistry on bioavailability to aquatic organisms.
- Utilization of a Reference Channel for the purpose of differentiating certain chemical constituents with respect to the background conditions when performing environmental characterization and analysis.2
- Estimation of biota sediment accumulation factors (BSAFs) from sediment to crabs and fish.
- Collection of site-specific information to support the Baseline Ecological Risk Assessment, including a biologic habitat assessment and the collection of tissue residue in selected aquatic biota in South Branch Creek and the confluence area of South Branch Creek and Arthur Kill.
- Evaluation of sediment toxicity.

1.4.3 Off-Site Ditch Investigation

Comment [PJT22]: Ditch Report

Off-Site Ditch Work Plan Documents

The off-site ditch investigation phase of the RI was performed from July 22, 2011 to July 28, 2011 in accordance with the following two USEPA-approved documents:

- "Revised Scope of Work - Characterization of Off-Site Ditches, LCP, Chemicals Inc. Superfund Site", (Brown and Caldwell, May 14, 2010).
- "Quality Assurance Project Plan, LCP Chemicals, Inc. Superfund Site, Linden, New Jersey", (Brown and Caldwell, May 2010).

Off-Site Ditch Work Plan Objectives

The Off-Site Ditch Scope of Work included an approach and methodology to address the following technical objectives:

2 The Phase II RIWP documents, dated October 2006, included tasks for the selection and collection of samples from a reference stream. An e-mail message dated August 18, 2006 from Mr. Jon Gorin of USEPA to ISP-ESI that stated " . . . after consulting with BTAG, we've determined that there is no need for a reference stream right now." The approved documents included identification and sampling of a reference stream. This work was therefore conducted in accordance with the approved documents without oversight by USEPA.

- To characterize the extent to which the Northern and Southern Off-Site ditches are tidally influenced.
- To characterize the extent to which the Northern and Southern Off-Site ditches may be impacted by site-related constituents.

1.5 Report Organization

The data presented in this RI Report includes the Phase I and II RI data and is intended to characterize current site conditions for each medium that was investigated. The environmental database (Appendix F) contains the complete laboratory analytical data from both the Phase I and Phase II RI field investigations.

The RI Report is organized as follows:

- Section 1 Introduction
- Section 2 Site Setting
- Section 3 RI Field Investigation Methods and Procedures
- Section 4 Data Management
- Section 5 Physical Characteristics
- Section 6 Nature and Extent of Contamination
- Section 7 Contaminant Fate-and-Transport
- Section 8 Baseline Risk Assessment Summary
- Section 9 Recommendations
- Section 10 References

Appendices to the RI Report are as follows:

- Appendix A Property Transfers
- Appendix B Field Operations Plan
- Appendix C Well Construction and Soil Boring Logs
- Appendix D Hydrogeologic Data
- Appendix E Wetland Delineation
- Appendix F Habitat Assessment Report
- Appendix G Representative Photographic Logs
- Appendix H Analytical Lab Deliverables (DVD)
- Appendix I Data Usability Reports
- Appendix J Tabular Summary of Analytical Data
- Appendix K Environmental Database (CD-ROM)
- Appendix L Alternate Groundwater Quality Criteria
- Appendix M Sediment Toxicity Testing Report
- Appendix N Regional Studies
- Appendix O NJDEP Technical Regulations Checklist
- Appendix P Human Health Risk Assessment
- Appendix Q Ecological Risk Assessment

Section 2

Site Setting

The LCP Chemicals Inc. Superfund Site (LCP site) is located in the Tremley Point section of the City of Linden, Union County, New Jersey as shown on Figure 1-1. The site is located along the western shore of the Arthur Kill and east of the New Jersey Turnpike. It is accessed from the Road to Grasselli which is reached from Linden via South Wood Avenue and Tremley Point Road. The coordinates of the center of the site are Latitude 40.60832° and Longitude -74.21163°.

The LCP site property includes Block 587, Lots 3.01, 3.02, and 3.03. The area of these three lots totals approximately 26 acres. The shape of the property is highly irregular with a maximum east-west dimension of approximately 2,500 feet and a maximum north-south dimension of 1,600 feet (Figure 3-1).

The site is bisected by an inactive railroad spur running north and south that is located on an easement and is operated by the Consolidated Rail Corporation (Conrail). The LCP chlor alkali manufacturing facility was formerly housed in a group of buildings located immediately west of the railroad tracks. The mercury cell buildings (No. 230 and 240) and the liquefaction building (No. 231) are shown on Figure 1-3.

The current alignment of a man-made ditch, known as South Branch Creek, is located east of the railroad tracks along a narrow portion of the property that connects to the Arthur Kill. Occupying most of the remaining portion of the property east of the railroad tracks is a closed RCRA unit, a cooling tower, and the pad for a former sludge roaster. The closed RCRA unit is currently maintained by ISP-ESI.

West of the railroad tracks there are numerous buildings and tanks associated with the LCP Chemicals Inc. facility and its tenants. Several of the buildings also exist on the property that were part of associated processes leased and operated by other companies, including the Linde hydrogen plant predominantly on the western portion of the property, and the Kuehne Chemicals sodium hypochlorite and chlorine packaging facility. Other notable site features on the western portion of the site include an electrical transformer and rectifier yards and an on-site railroad yard. Additionally, engineering and institutional controls consisting of a 0.7 acre asphalt cap and deed restriction were placed on the western portion of the property by former tenant Linde in 1994 pursuant to the New Jersey Environmental Responsibility Act (ECRA) Site No. 90367. This engineering control installed by Linde, the cap, has not been inspected or maintained by Linde or its successors, including Praxair to the knowledge of ISP ESI, at any time after installation in 1994. The cap is currently in disrepair with major cracks and trees growing out of it. NJDEP, EPA and Praxair have been notified of this situation on several occasions.

The LCP site started chlor-alkali manufacturing operation in 1955 and the core of the manufacturing buildings were present by 1956. Cell Building 240 was added in 1972. Manufacturing of chlorine ceased at the facility by August 1985 and site operation by LCP ended by August 1994; several tenant operators remained until 2001. Additional information regarding the site history, including site operation and development is presented in Section 1.3.

The southern LCP property is adjacent to a pair of parallel railroad tracks operated by Conrail, and further south by two parallel drainage channels hereinafter referred to as the Northern and Southern Off-Site Ditches. The two ditches run parallel with the southern LCP property line, and are not apparently associated with development on the LCP site.

Comment [PJT23]: Ditch Report

2.1 Land Use and Zoning

The area surrounding the LCP site historically was developed for heavy industrial use, much of which is currently inactive. A map depicting land use as of 2002 is presented in Figure 2-1. The map was developed based on GIS datalayers obtained from the New Jersey Department of Environmental Protection (NJDEP).

The current primary active land use in the area is bulk storage and transport of petroleum products and aggregates. The transport of these materials occurs by ship and barge using dockage along the Arthur Kill as well as by rail, truck, and pipeline. Other active facilities in the area include a municipal wastewater treatment plant, trucking and warehousing, and truck repair. An active, major rail freight line runs parallel to the eastern side of the New Jersey Turnpike, west of the site. A number of large chemical manufacturing facilities formerly operated within one mile of the site, most of which are currently inactive and in various stages of demolition and site remediation.

The industrial properties located immediately adjacent to the LCP site include:

- NuStar Energy Linden Terminal located north and south of South Branch Creek to the east of the inactive Conrail railroad spur.
- The former GAF site manufacturing facility to the north.
- Citgo Petroleum Corp, Linden Transload Terminal located to the south and southwest.
- Linden-Roselle Sewerage Authority (LRSA) sludge barge dock located southeast of the site along the Arthur Kill.

Various undeveloped areas are located within one mile of the site, many of which are either vacant former chemical manufacturing plants or tidal wetlands. The former manufacturing areas are depicted on the Land Use map (Figure 2-1) either as “Industrial”, “Undeveloped/Barren/Field”, and/or “Scrubland”. Areas of tidal wetlands, some of which are partially filled, are located along the Rahway River to the south and Piles Creek to the north. Pralls Island is located northeast of the site and across the Arthur Kill in Richmond County, New York and is a wildlife sanctuary consisting of dredge spoil fill placed over former tidal wetlands. The City of New York, Department of Sanitation Fresh Kills Landfill, is located approximately three miles south of the site.

Most of the currently or formerly developed land in the vicinity is located on what has been mapped by the New Jersey Geologic Survey (2005) as “Historic Fill” in accordance with N.J.S.A. 58:10B-1 et seq. Additional information regarding anthropogenic fill is presented in Section 1.3.2.

The only area of residential development within one mile of the site is the Tremley section of Linden which is located west of the New Jersey Turnpike approximately 3,850 feet (¾ mile) from the nearest (western) edge of the LCP site.

2.1.1 Anthropogenic Fill

The entire area of the LCP site and most of the area surrounding the site formerly consisted of tidal wetlands, as depicted on historic topographic maps in Figures 2-2 through 2-4. It was necessary to raise the grade prior to the historic development of these areas for industrial and other uses. This was accomplished through the placement of non-indigenous materials, that is, materials not originally native to the tidal wetlands, including soil, ash, dredge spoil, demolition debris, and other materials. This material is referred in this report as “anthropogenic fill”, namely, fill material that has been placed by humans. The placement of fill in the Tremley Point area allowed for the industrial development of the peninsula.

~~**Definition of Historic Fill**~~

~~The anthropogenic fill found on the LCP site and the site vicinity meets the definition of "Historic Fill" contained in the New Jersey "Technical Requirements for Site Remediation" [N.J.A.C. 7:26E 1.8]:~~

> ~~"Historic fill material" means non indigenous material, deposited to raise the topographic elevation of the site, which was contaminated prior to emplacement, and is in no way connected with the operations at the location of emplacement and which includes, without limitation, construction debris, dredge spoils, incinerator residue, demolition debris, fly ash, or non hazardous solid waste. Historic fill material does not include any material which is substantially chromate chemical production waste or any other chemical production waste or waste from processing of metal or mineral ores, residues, slag or tailings. In addition, historic fill material does not include a municipal solid waste landfill site.~~

~~The "Brownfield and Contaminated Site Remediation Act" [N.J.S.A. 58:10B-1 et seq.] required the NJDEP to map regions of the state where large areas of historic fill exist and make this information available to the public. Mapping of historic fill has been provided as a GIS datalayer "DGS04-7 Historic Fill for New Jersey as of December 2005", and "includes the area underlain by areas greater than 5 acres containing non indigenous material placed on a site in order to raise the topographic elevation of the site". The following is excerpted from the metadata accompanying the datalayer:~~

> ~~"Historic fill was mapped from stereo aerial photography taken in March 1979, supplemented in places by planimetric aerial photography taken in the spring of 1991 and 1992. Additional areas of fill were mapped by comparing areas of swamp, marsh, and floodplain shown on archival topographic and geologic maps on file at the N. J. Geological Survey, dated between 1840 and 1910, to their modern extent. In a few places, fill was mapped from field observations and from drillers' logs of wells and borings.~~
>
> ~~Most urban and suburban areas are underlain by a discontinuous layer of excavated indigenous soil mixed with varying amounts of non indigenous material. This material generally does not meet the definition of historic fill and is not depicted on these maps. Also, there may be historic fills that are not detectable on aerial photography or by archival map interpretation and so are not shown on these maps, particularly along streams in urban and suburban areas."~~

~~The NJDEP mapped areas of historic fill are depicted on Figure 2-1. It is evident that the anthropogenic fill covering the LCP site meets the criteria for Historic Fill given that NJDEP has mapped the entire site as being covered by Historic Fill. The fill was placed on the site to raise the elevation of the LCP site prior to development of the property for industrial use.~~

Historic Placement of Anthropogenic Fill

The presence of anthropogenic fill at the site has been verified by evaluation of soils encountered as part of the extensive soil boring program, which was completed as part of Phase I and II of the RI, as well as prior subsurface investigations conducted by others. This observation has been independently confirmed through an evaluation of the historic placement of anthropogenic fill identified on available historic maps and aerial photographs. Briefly, these sources (Figures 2-5 through 2-17) reveal that the entire area, formerly occupied by tidal marsh, was progressively filled. A chronologic description of the placement of anthropogenic fill is described below.

Comment [PJT24]: ES#1 – Revised Fig 2-1

Historic topographic mapping from 1898 (Figure 2-2) reveals that the entire LCP site was formerly occupied by tidal wetlands that were contiguous with the Arthur Kill. In fact, the only nearby area that was not wetland is the slightly elevated land along Tremley Point Road.

Early industrial development occurred immediately along the margin of the Arthur Kill with the construction and operation of the Standard Chemical Works and later the Grasselli Chemical Company. This presence of the Grasselli Chemical Company is evident on the 1898 topographic map (Figure 2-2).

Aerial photography as of May 8, 1929 (Figures 2-5 and 2-6), reveal what appeared to be extensive filling in the Grasselli East Works area (east of railroad tracks). This land was owned immediately prior to this time by the Grasselli Chemical Company and was later acquired by duPont, with a narrow strip owned by Grasselli Dyestuff Company. The fill was also identified as far south as South Branch Creek, evident by the apparent steep banks on either side of the creek located north of the LCP property (Figure 2-5). The area west of the tracks had apparently not yet been filled.

Available aerial photography from April 28, 1940 reveals extensive areas of filling located on what was likely the duPont property at the time located east of tracks (Figure 2-8). These areas include north and south sides of South Branch Creek between the confluence with Arthur Kill and the eastern-most railroad track, a triangular area immediately south of South Branch Creek and immediately east of the western railroad tracks, and the large area located north of South Branch Creek. Other areas may be filled, including the entire area of the future LCP property east of the tracks, although this is not completely clear from the photograph.

By 1940 the south-western portion of the future LCP property between the railroad tracks was filled in preparation for the construction of a railroad yard (Figure 2-8). This railroad yard was on property that was owned at the time by the Central Railroad Company of New Jersey (Figure 2-11).

An irregular area is evident on the 1940 photograph (Figure 2 8) that appears to have been filled. This possible fill area was located on property owned by duPont that was located immediately north of railroad track, contiguous with South Branch Creek. The area immediately north of South Branch Creek is apparently not filled, as well as the far southeast corner of the future LCP property (west of the tracks).

By July 1947 (Figure 2-10), aerial photographs reveal that the northern portion of the property is covered with raw material piles on property owned by General Aniline & Film Corporation. These material piles and decommissioned process equipment storage yard are located in an area that has obviously been filled. South Branch Creek has now been re-routed to a position further south.

The old alignment of South Branch Creek is evident in the photographs from 1951 in which it and the area surrounding it are in the process of being filled (Figures 2-11 and 2-12). This is located on land that had been acquired by General Aniline & Film Corporation from duPont just shortly before in 1949. The northwestern most corner of the LCP property is partially filled along what appears to be a road leading to the western portion of the GAF facility. A strip of empty land immediately to the south is apparently not yet filled.

As of July 17, 1952, aerial photography indicates that the northern portion of the property remains covered with raw material piles and a process equipment storage yard in an area that has obviously been filled. South Branch Creek has now been re-routed to a position further south. The old alignment of South Branch Creek is still evident in the photograph in which it and the area surrounding it have been filled. The new (southern) alignment of South Branch Creek is evident. The entire western portion of the LCP property has now been filled. The most recent area of filling is partially covered with rows of equipment (Figure 2-12). In a photograph dated May 16, 1954 (Figure 2-13), the entire site east of the tracks appears to have been filled.

In summary, most filling of the LCP property was performed over a long time span likely starting around 1885. Much of the filling occurred by various owners prior to the development of the site for chlor alkali production. Most, but not all of the property, appears to have been filled by 1949.

2.1.2 Regional Industrial History

A brief description of some of the major industrial occupants of the Tremley Point area is presented below. Information contained herein was obtained from NJDEP files, the attached title search summary, or was provided by the property owner. ISP-ESI has not conducted an independent investigation of any of these properties or their operations. The historic regional land use circa 1940 is presented in Figure 2-3.

Former GAF Chemicals Manufacturing Facility

The former GAF Chemicals manufacturing facility, now referred as the GAF site, was first utilized for chemical manufacturing in approximately 1919. Under the various ownerships, chemical products were manufactured at the GAF site from approximately 1919 until closure of the plant in April 1991. Products manufactured at the GAF site primarily consisted of dyestuffs and surfactants, but also included ethylene oxide, tetrahydrofuran and herbicides. The plant ownership and various corporate entities are described in Section 1.3.1. The current owner of the site is Linden Property Holdings LLC.

The GAF site has been remediated ~~remediated by ISP ESI~~. The site remediation conducted to-date has included demolition of site structures, capping, grading and drainage improvements, construction of a shallow groundwater barrier and groundwater collection system, installation of bedrock groundwater extraction wells, LNAPL collection and the construction and operation of a groundwater conveyance and treatment system. NFA letters have been received for site-wide soils and groundwater from the NJDEP. Remedial Action Permits for Groundwater (Permit ID RAP110002) and Soil (Permit ID RAP110001) became effective at the GAF Site on February 22, 2012.

The environmental conditions at the GAF site were documented in a comprehensive Remedial Investigation Report (Eckenfelder, 1991). Raw materials and associated bi-products from the former GAF operations are reported to have included arsenious acid catalysts, arsenic acid, arsenic mercuric sulfate, and mercury oxide catalysts among numerous other organic and inorganic constituents. The predominant organic constituents in soils and groundwater include various VOCs and SVOCs, including chlorobenzene, benzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, naphthalene, 4-chloroaniline, and phenol. The most prominent inorganics in soils and groundwater were mercury, chromium, and arsenic. These constituents are widely distributed across the entire Site with the highest levels observed in the "Old Landfill" and in the former production area. In fact, dissolved mercury concentrations range as high as 2,520 µg/L in the bedrock water-bearing zone.

A groundwater barrier wall formed of sealed-joint, steel sheet piling (Waterloo Barrier) was installed to provide hydraulic containment of shallow groundwater, and to limit the potential for contaminated soil particle migration from the site. The groundwater barrier wall spans a length of approximately 8,523 feet and surrounds an area of approximately 104 acres. Its alignment encompasses the former main plant site of the GAF site (Figure 2-X). The wall penetrates miscellaneous fill materials and is keyed into the underlying organic silt and clay aquitard and/or the glacial till formation.

A shallow groundwater collection system is installed just inside the barrier wall to intercept and control potentially contaminated shallow groundwater and percolations above the aquitard and direct these waters to the on-site wastewater treatment plant. This shallow groundwater collection system, in conjunction with the barrier wall, controls the interior shallow groundwater elevation, such that intragradient conditions (i.e., hydraulic head on the inside of the barrier wall is below that on the outside) prevail along the length of the barrier wall, thus containing shallow groundwater within the limits of the barrier wall and controlling the lateral migration of groundwater from the GAF site. This system consists

Comment [PJT25]: Updated for accuracy

Comment [PJT26]: Updated for accuracy

Comment [PJT27]: Updated for accuracy

Comment [PJT28]: GC#1

Comment [PJT29]: SC#13 – New Figure Inserted

of a collection drain situated essentially parallel to and a short distance inside the barrier wall alignment. The drain includes a 15-inch diameter high density polyethylene perforated pipe surrounded by drainage stone, which is wrapped in a geotextile blanket. A series of 26 precast concrete manholes serve as inspection and maintenance points along the length of the drain. Collected waters within this system are directed to two pumping stations, each consisting of an above-grade pump house situated over a precast concrete collection sump. Each pump station is equipped with a primary and backup pump, liquid level sensors and controls to operate the pumps and maintain groundwater at the desired elevation. Water discharged from each pump station is conveyed to the WWTP.

A bedrock groundwater extraction system provides areal hydraulic capture of the GAF site. Primary hydraulic capture of the majority of the site is provided by two wells located on the eastern edge of the site, DEW-2 and DEW-4A (Figure 5-14) with well screen intervals of 45 to 65 ft bgs and 45 to 55 ft bgs, respectively. Extraction wells DEW-2 and DEW-4A are operated in a continuous pumping mode at 18-20 gpm each, and have been operational on a nearly continuous basis since 2002. Additional, minor hydraulic capture of the northern edge of the GAF site has been achieved by two extraction wells, EW-2, and DEW-2, that became operational in early 2010, at pumping rates of approximately 1 to 2 gpm each. Water from the bedrock extraction system is conveyed to the on-site waste water treatment facility.

Comment [PJT30]: SC#13

NOPCO

A NOPCO Chemical Company ("NOPCO") chemical manufacturing site was located immediately south of the LCP site on land now occupied by NuStar Energy. The NOPCO facility is observed on a 1966 aerial photograph (Figure 2-16). NOPCO constructed a toluene diisocyanate manufacturing plant on the site in the early 1960s with an initial design capacity of 10 million pounds per year. Raw materials used in the production of toluene diisocyanate include phosgene, chlorobenzene, and dichlorobenzenes, among others. Toluene diisocyanate is used as an intermediate in the production of polyurethane. The NOPCO Linden operation was related to its "Lockfoam" product line.

NOPCO acquired the land to construct the toluene diisocyanate plant from Sinclair Refining on December 28, 1960. The plant was constructed in the early 1960s and full operation was initiated by March and April of 1963. However, the plant operations were discontinued by September 1964 after a long series of design, construction, and operational difficulties. NOPCO sold the property to Allied Chemical Corp on April 5, 1965 (NOPCO Chemical Company, 1960, 1961, 1962, 1963, 1964, 1965). NOPCO Chemical merged into the Diamond Alkali Company who shortly thereafter merged with the Shamrock Oil Company to form the Diamond Shamrock Corporation in 1967.

E. I. duPont de Nemours and Company (duPont) Site

The duPont site is currently located northeast of the LCP site along the Arthur Kill. This former chemical manufacturing site has been decommissioned and is currently in the ISRA process.

The duPont plant manufactured inorganic salts and acids, organic pesticides (including DDT), sulfuric acid, ammonium thiosulfate, and a sodium bisulfate solution. duPont used areas of surrounding marsh for discharge of aqueous manufacturing wastes from 1928 until the mid-1970s. The wastes disposed of were from the manufacture of inorganic compounds such as phosphate plaster (CaSO4 with 2-3% phosphate residual), hypo muds (diatomaceous earth, sulfur, carbon, and rust particles), silicate muds (sand, filter aid, and minor quantities of sodium silicate), and metal sulfides. The wastes also included coal, coal ash and waste residues. Various arsenic-containing materials are reported to have been manufactured including lead arsenate, iron arsenate, and arsenic acid, in addition to various pesticides that may have included arsenic.

Comment [PJT31]: SC#2

Comment [PJT32]: GC#1

The parcel has been used for chemical manufacturing from about 1880 until 1990 when duPont ceased operations.

Petroleum Product Terminals

Comment [PJT33]: GC#1

Two bulk petroleum product terminal facilities are located on properties immediately adjacent to the LCP site. The NuStar Energy-Linden Terminal is located north and south of South Branch Creek to the east of the inactive Conrail railroad spur on the property previously occupied by NOPCO. This facility has been in existence under various ownerships since the 1970s. The Citgo Petroleum Corp, Linden Transload Terminal located to the south and southwest of the site has been in existence since before 1940. These facilities receive and ship various products including petroleum distillates, gasoline, jet fuel, ethanol, and other residual fuels. The mode of product receipt includes ship, barge, rail and pipeline. The mode of delivery includes ship, barge, pipeline, and truck.

Bayway Refinery

The Bayway Refinery is located west and northwest of the LCP site. The facility is approximately 1,300 acres with a refinery, two chemical plants, tank fields, and a marketing and distribution station. The refinery has been producing petroleum products in continuous operation since 1909. The eastern border of the property abuts the western headwaters of Piles Creek. Various ownership changes have occurred over the years. Standard Oil Company purchased the Bayway property in 1907. Successors included Standard Oil of New Jersey and Exxon. More recent ownership has included Tosco Corp and ConocoPhillips. The facility is currently under an Administrative Order and has triggered ISRA several times. It is our understanding that Exxon-Mobil retains the liability for the environmental cleanup of the site.

On the eastern side of the Bayway Refinery, the New Jersey Turnpike passes through the site, separating the main refinery and process areas from the waterfront area, which borders on the Arthur Kill. Two outlying tank fields (the Rahway River Tank Field and the 40-acre Tank Field) are located southwest of the main refinery and process areas.

The west side chemical plant produces additives for motor oils and high purity propylene. Tanks on site store sulfidic caustic, asphalt, butane, gasoline additives, heavy catalytic naptha, domestic oil, gasoline, petrolite, Celsius, water white, standard white, gas oil, treated naptha, crude naptha, and crude petroleum. The east side chemical plant produced methyl ethyl ketone, tertiary butyl alcohol, secondary butyl alcohol, methyl isobutyl ketone, isopropyl alcohol, acetone, propylene, isophorone, and fuel gas. Finished products stored on site include heating oil, heavy fuel oil, jet fuel, diesel fuel, kerosene, asphalt. There is a tetraethyl lead building. Processes include calatytic cracking, naptha reforming, alkylation, and disulfurization. Early products produced on site (1914-1919) included gasoline and kerosene.

Former American Cyanamid Warners Plant

The former American Cyanamid Warners Plant was located at the tip of the Tremley Point peninsula at the confluence of the Arthur Kill and the Rahway River. The 33-acre site was built in 1916-1917 and originally produced concentrated "ammo-phos" fertilizers. During WWI, the facility produced ammonia and nitric acid for military purposes. The plant also made aluminum sulfate for water treatment and a range of organic chemicals including rubber, motor oil additives, accelerators, fumigants (hydrocyanic acid) and pesticides. A sulfuric acid production unit started operation in 1970. The facility discontinued operations in 1998.

The site has been decommissioned and an environmental remediation has been performed under RCRA. The property has been sold and is currently awaiting redevelopment.

PSE&G

The PSE&G Linden Generating Station is a 1,526 MW natural gas powered electric power plant located along the Arthur Kill immediately north of Piles Creek. This plant replaced a former oil-fired plant that was also operated by PSE&G.

2.1.3 Current Site Land Use

Manufacturing of chlorine ceased at the LCP facility in 1985 and site operation by LCP ended by August 1994. Several tenant operators, including Active Water Jet, Inc. remained until 2000. Today, the LCP site is unoccupied and unused.

2.1.4 Zoning

The area of the site located east of the New Jersey Turnpike (NJTP) is zoned for heavy industry. Allowable uses in this area include various types of manufacturing (except explosives, fertilizers, and the use of liquefied natural gas); assembly and packaging; warehousing; airports; offices, research facilities; service stations and automotive repair shops; public utility generating stations, truck terminals and tank farms. Residential, consumer retail, and recreational development in the area located east of the NJTP is specifically not allowed.

Some of the areas located along South Wood Avenue, west of the New Jersey Turnpike, are zoned for light industry. Allowable uses for these areas would include manufacturing that employs no chemical or raw material processing, assembly and packaging operations, warehousing, airports, offices and research facilities, and service stations and automotive repair shops.

2.1.5 Anticipated Future Land Use

The Tremley Point area of Linden, located east of the New Jersey Turnpike, is anticipated to undergo brownfields redevelopment on the sites of the former manufacturing facilities. A major transportation infrastructure has been in the planning stages to support this redevelopment. Specifically, New Jersey Department of Transportation (NJDOT, 2008) "Tremley Point Access Local Roadway Improvements", Project ID 9324A is anticipated to be funded as part of the FY 2009 Transportation Capital Program that will consist of a four-lane, 1.1 mile long roadway and bridge to connect Tremley Point with Exit 12 of the New Jersey Turnpike in Carteret. This project is specifically intended to address "the increase in truck traffic anticipated by the redevelopment of the Tremley Point brownfields into more than six million square feet of warehouse and distribution space" (NJDOT, 2008).

Potential future land uses of the LCP site may include power generation, petroleum terminals, warehousing and distribution, and transportation.

2.2 Demography

In the following sections, demographic information (including population, economic indicators, and labor information) is presented and discussed. Data are reported for areas in New Jersey within a one mile radius of the site's boundaries. Much of the data reported are based on 2000 census data.

2.2.1 Population

Population distribution for cities and townships in the vicinity of the LCP site is summarized on Table 2-1. Included are population data for the Cities of Elizabeth, Linden, and Rahway (of Union County) and the City of Carteret (of Middlesex County). As shown, the City of Elizabeth is the most densely populated (9,865.5 persons per square mile) and also has the largest population (120,568 persons) of the jurisdictional areas evaluated.

Change in population from 1980 to 1988 is also shown in Table 2-1. Union County has experienced an increase in population of 5.8 percent for the period of 1990 to 2000. Elizabeth, Linden, and Rahway have significantly gained in population (9.5 percent, 7.2 percent, and 4.7 percent change in population, respectively). Middlesex County experienced a significant 11.6 percent gain in population over this time period. The population change for Carteret increased 8.9 percent during this time. These data indicate

that, in general, the area in the region of the LCP site experienced a growing trend in population during the period of 1990 to 2000.

Only a slight increase in population was expected for Union County for the time period 2000 and 2006 (1.6 percent), while a more sizeable increase in population (4.9 percent) was anticipated for Middlesex County during the same time period.

In Table 2-2, population distribution by age group is presented. As shown, the highest percentage of the population for the jurisdictional areas evaluated is within the working age group of 18 to 64 years. The City of Linden has the greatest amount of residents aged 65 years to older (at 16.3 percent) while the City of Elizabeth has the smallest amount (at 10.0 percent). This is also reflected by median age reported with Linden having the highest median age (38.0 years) and Elizabeth having the lowest (32.6 years).

2.2.2 Economic Indicators

Per capita income for the jurisdictional areas evaluated is reported in Table 2-3. In 1999, per capita income for the cities of Elizabeth, Linden, and Rahway were substantially less than that for Union County, with the City of Elizabeth having the lowest ($15,114). Similarly, the 1987 to 1999 percent increase in income for the City of Elizabeth (42.5 percent) was lower than that for Linden (57.3 percent) or Rahway (60.3 percent). The City of Carteret had a lower per capita income than the rest of Middlesex County; however, the per capita income reported for Woodbridge Township ($25,087) was very close to the number reported for Middlesex County ($26,535). The 1987 to 1999 percentage increase in per capita income was significantly less for Carteret (47.7 percent) compared to Woodbridge Township (71.1 percent).

Household income data reported for 1999 and 2004 are shown in Table 2-4. Median household incomes were somewhat higher for Middlesex County ($60,987) compared to Union County ($55,247). The percent of persons living below the poverty level in the City of Elizabeth was a substantial portion of the population (17.8 percent) and was over twice the number for Union County (6.4 percent). A similar trend was reported for families living below the poverty level in 2000; the percentage reported for the City of Elizabeth was 15.6 percent versus 5.0 percent for the City of Linden.

2.2.3 Labor Information

Available data on the civilian labor force for cities and counties in the vicinity of the LCP site are shown in Table 2-5. In 1999, the City of Carteret had the largest percentage of unemployed (at 5.8 percent) followed by the City of Elizabeth (5.2 percent), the City of Rahway (4.3 percent), and the City of Linden (3.6 percent). Union and Middlesex Counties displayed similar percentages of unemployed residents—3.5 percent and 3.4 percent, respectively.

Employment data by industrial category (1999 data) for Union and Middlesex counties is presented in Table 2 6. Employment trends are slightly different from what they were during the last census. The manufacturing industry accounted for the highest percentage of jobs in Middlesex County at 18.6 percent while the education and healthcare industries accounted for 18.4 percent in Union County. The retail trade industry is also a major employer in both counties. The agricultural and mining industry employs only a minor portion of the employed populations in Middlesex and Union counties (0.1 percent in both counties).

2.2.4 Summary of Demographic Characteristics

In summary, the New Jersey jurisdictional areas within a one-mile radius of the property boundaries are experiencing a slight increase in population. Only a small increase in population was projected in Union County to the year 2006 (1.6 percent increase) and a somewhat greater increase was projected for

Middlesex County (4.9 percent). The majority of the population living in the region of the LCP site is of working age (18 to 64 years old). Of the jurisdiction areas evaluated, the City of Linden has the highest percentage of residents over the age of 65 years and also the highest median age (38.0 years).

Per capita income in 1999 for the cities of Elizabeth, Linden, and Carteret is substantially less than their respective counties. The lowest per capita income ($15,114) was reported for the City of Elizabeth. The percentage of persons and families living below the poverty level was also highest for the City of Elizabeth and represents a substantial portion of the population (17.8 and 15.6 percent, respectively). The percentages of persons and families living below the poverty level for the remaining jurisdictional areas were 11.0 percent or less and 8.6 percent or less, respectively.

The percentage of the total civilian labor force that was unemployed ranged from 3.4 percent (Middlesex County) to 5.8 percent (City of Carteret) in 1999. The majority of the work force in Middlesex and Union counties was employed in the manufacturing, education and the health care industry, and retail trade industries as of 1999.

2.3 Climate and Meteorology

Climatological data are recorded at the NOAA measuring station located at Newark Airport in Newark, New Jersey. The LCP site is located approximately seven miles south of the recording station. The elevation and topographic setting of the LCP site are very similar to that of the NOAA station such that the NOAA data provide an accurate representation of the climatology of the site. The climatology for the area was obtained from Comparative Climatic Data for the United States (NOAA, 2000) and monthly summaries up through 1998 (NOAA). Mean temperature and precipitation data contained therein are based upon a thirty-year period of record from 1961 to 1990 referred to as "normals". Wind direction and speeds are based upon records since 1944.

2.3.1 Temperature

Average daily temperatures range from a normal daily maximum of 87.0°F in July to a normal daily minimum of 23.4°F in January. The normal monthly temperatures range from 77.8°F to 30.6°F (Table 2-7) and occur in the months of July and January, respectively. The average 30-year normal of the average monthly temperatures for the period of record is 54.8°F. The average normal daily maximum is 63.4°F and the average normal daily minimum is 46.1°F. Although the average normal monthly temperature varies greatly, with an average deviation of 14.3°F, these temperatures occur in a relatively normal distribution (Figure 2-18), with July being the warmest month and January and February comprising the colder months on either side of the temperature distribution. Occurrences of extreme temperatures have been recorded as high as 105°F in July of 1966 and as low as 8°F in January of 1985.

2.3.2 Precipitation

The 30 year normal of the annual precipitation is recorded as 43.97 inches (Table 2-7). The annual precipitation is fairly uniformly distributed throughout the year (Figure 2 19) with a mean deviation of 0.30 inches. Extreme monthly precipitation values have been reported as high as 13.22 inches in October 2005 and as low as 0.07 inch in June 1949. The mean maximum precipitation for a 24-hour period is reported as 7.84 inches in August 1971. Relative humidity for the region averages 73 percent at sunrise (0700 hours) and 53 percent at sundown (1900 hours). Although slightly higher relative humidity readings are reported for the months of August through January, mean monthly readings occur in a generally uniform distribution throughout the year.

2.3.3 Prevailing Wind Direction and Speed

The prevailing wind direction for the area is from the southwest during the months of May through December as determined by data compiled by NOAA, since 1944. However, during the months of February through April, the prevailing wind direction is from the northwest or west-northwest. The mean wind direction in January is from the northeast.

The mean prevailing wind speed is reported as 10.2 miles per hour (mph), and varies from 11.9 mph in March to 8.7 mph is August (Table 2-7). Higher mean wind velocities occur during the months of November through May, while lower velocities are observed in the months of June through October. The highest wind speed (fastest observed one min value) recorded at the Newark Weather Station is 82 mph in November 1950. The next highest wind speed is recorded at 58 mph in December 1984.

2.4 Surface Water Bodies

In the following sections, information (including surface water features and classifications) is presented and discussed. Information is provided for both the region and for areas within the LCP site's boundaries.

2.4.1 Regional Surface Water Features

Tidal marsh formerly covered the entire area in which the LCP site is now located. Nearly all developed land in the Tremley Point area, inclusive of the LCP site, constitutes man-emplaced fill material laid over the former tidal marsh. Therefore, the topography of the area is relatively flat, with an elevation of only a few feet above sea level. The primary exception is the naturally-occurring high ground southwest of the LCP site along which Tremley Point Road runs. Additional information regarding the placement and distribution of anthropogenic fill is presented in Section 2.1.1.

The LCP site is almost entirely surrounded by tidal water bodies. Most prominent among these is the Arthur Kill, which is a large tidal straight that connects Newark Bay and Kill van Kull to the north and Raritan Bay to the south. The Rahway River, with a drainage area of 41 mi^2 (Rahway River Association, 2008) joins the Arthur Kill just south of the site. Piles Creek is a small tidal creek that connects to the Arthur Kill immediately north of the adjacent GAF site. To the west of the LCP site is the tidal stream known as Marshes Creek, which is a tributary of the Rahway River. Relatively extensive areas of unfilled tidal marsh exist along the lower reaches of the Rahway River, Marshes Creek, and Piles Creek.

Other tidal streams located further from the LCP site include Morses Creek and the Elizabeth River which flow into the Arthur Kill north of the site; and Kings Creek, which is another small tributary of the Rahway River, located west of the site. A number of tidal creeks enter the Arthur Kill from Staten Island including, from north to south, Old Place Creek, Pralls Creek, Sawmill Creek, Neck Creek and Fresh Kills. The locations of each of the surface water bodies are depicted on Figure 2 20.

2.4.2 Surface Water Classifications

The major surface water bodies located near the LCP site, including the Arthur Kill and the Rahway River, have been classified under the NJDEP Surface Water Quality Standards, N.J.A.C. 7:9B-1.15.

The Elizabeth reach Arthur Kill, along which the site is located, is classified as SE3. The designated uses of SE3 waters include: secondary contact recreation; maintenance and migration of fish populations; migration of diadromous fish; maintenance of wildlife; and any other reasonable uses [N.J.A.C 7:26B-1.12(f)].

The lower tidal reach of the Rahway River is classified as SE2. The intended uses of SE2 waters include maintenance, migration and propagation of the natural and established biota; migration of diadromous fish; maintenance of wildlife; secondary contact recreation; and any other reasonable uses [N.J.A.C 7:26B-1.12(e)].

2.4.3 Flood Hazard

Flood insurance studies for Union County, New Jersey (FEMA, 2006) reveal that various areas of the City of Linden are subject to both tidal (coastal) and fluvial (riverine) flooding. The tidal wave velocities are dampened by the meanders of the stream channels such that the tidal influence is less severe than the fluvial flooding along more inland local waterways. The City of Linden is subject to fluvial flooding along Morses Creek, Peach Orchard Brook, and Kings Creek which is caused by rivers and streams overflowing their banks. The Arthur Kill and its tributaries account for tidal flooding in the area. Water levels in these waterways are controlled by tidal conditions.

As stated previously, the site is nearly completely surrounded by tidal water bodies, including the Arthur Kill and its tributaries. The Arthur Kill (and its tributaries) are subject to tidal and coastal flooding influence and are not subject to riverine flood hazards. In addition, the facility is located outside of the influence of fluvial flooding by Morses Creek, Peach Orchard Brook, and Kings Creek. Therefore, the LCP site is not subject to riverine flooding.

Coastal flooding is caused by long and short wave surges that affect the shores of the open ocean, bays, and tidally influenced rivers, streams, and straights (such as the Arthur Kill). The movement of coastal waters is influenced by the astronomic tide and meteorological forces such as northeasters and hurricanes. Flooding is primarily the result of storm surges, wave setup, and wave run-up which occur during hurricanes and northeasters.

The 100-year tidal flood elevation has been established by FEMA (2006) at 8.4 feet NGVD, a level that would flood most of the LCP site.

2.4.4 Navigational Dredging

The Arthur Kill is a large, highly industrialized navigational tidal straight. It is tidally influenced by the New York Harbor and the Atlantic Ocean. Given the depositional character of the water body, it is necessary to periodically dredge the navigation channels to maintain this important waterway for commercial shipping. The dredging responsibility lies with the United States Army Corps of Engineers (USACE).

Dredging in the Arthur Kill has been performed since the 1870s when the navigational channel was first dredged to the depth of 16 feet (New York Times, 1873). In the recent decades, the navigation channel has been maintained at the depth of 35 feet and a width of 600 feet. A massive harbor improvement project is currently underway in which the navigational channels in the Arthur Kill will be deepened by dredging to a depth of 41 feet. The longer term plan will be to further deepen the Arthur Kill navigational channel to 50 feet (Port Authority of New York and New Jersey, 2008). The ongoing and planned future dredging necessarily results in the removal of huge amounts of sediment.

2.5 LCP Structures

2.5.1 Buildings

The chlorine production facilities that comprise the majority of the site were first constructed between 1954 and 1956. Cell Building No. 240 and other structures were not constructed until LCP ownership in the early 1970s. A brief description of the usage and history of the structures involved in the chlorine production, as well as the hypochlorite and hydrogen production facilities still found on the site follows below (Figure 1-3).

Building 223 – Kuehne Chemical Inc., Hypochlorite Facility – This facility was leased in 1972 and produced sodium hypochlorite (Bleach) from chlorine and sodium hydroxide transferred to the structure from the Chlorine facilities via overhead pipes. Chlorine, sodium hydroxide, hydrochloric acid and sodium hypochlorite were also stored and distributed from this facility.

Buildings 230 and 240 - Building 230 was the original mercury cell room that was built with the rest of the plant in the mid 1950s and contained 42 mercury cells. Building 240, the "new" cell room, was constructed sometime around 1972 and it contained 40 mercury cells. Process wastewater, brine spills, and mercury cell wash water in the buildings drained to concrete floor trenches, collected in sumps in the northeast corner of each cell building, pumped to holding tanks, and eventually pumped to a wastewater treatment system. Mercury was reportedly recovered from separators in the sumps and returned to the cells. A new concrete floor was poured over the old one in January 1981 due to the observation of cracks in the old floor.

Building 230 is among the most dilapidated structures at the site. Portions of the concrete block walls and individual concrete roof panels have periodically collapsed. However, this steel-framed building has not shown evidence of catastrophic failure and associated collapse. While the condition of Building 240 appears to be relatively un-degraded, the condition of the members that support a large gantry crane is not known.

Building 231, Liquefaction Building, Purasiv Area – Building 231 originally housed compressors and other equipment for chlorine liquefaction. An HCl burner and a commercial hydrogen gas purification unit ("Purasiv") used for the removal of mercury were located south of the building. A former electric substation, diesel generator, and wastewater area were located immediately north of the building.

Building 233 – Brine Building – Brine was treated and filtered in the brine treatment tank within Building 233. This included adding sodium hydroxide, sodium carbonate, and barium chloride to precipitate impurities out of solution. The remaining precipitates were transferred to the Brine Sludge Lagoon. Prior to the construction of the Brine Sludge Lagoon in the 1960's, it is unknown where the sludge was disposed of. The concrete block walls of this steel-frame building are substantially degraded.

Building 250 - Warehouse – The mortar between the concrete block in the walls appears to be substantially degraded. Portions of the warehouse may be in jeopardy of collapsing. However, the warehouse is a relatively small structure and no hazardous materials are known to presently exist within it.

Linde Hydrogen Plant - This structure was leased from the Owners of the site and operated from 1957 1990. Hydrogen produced from the chlorine process in Buildings 230 and 240 was piped to this facility where it was purified and stripped of mercury. Prior to the occupation by a new tenant, the lessee UCC had the building and equipment decontaminated and sampled for mercury. In 1990 the expiration of the lease prompted an ECRA investigation. An environmental investigation and cleanup followed, with NJDEP approving "No Further Action" (NFA) in 1995. The property was later used by Liquid Carbonic Corporation for office space and truck parking.

Salt Unloading - Salt to be used in the preparation of brine for the chlorine process was unloaded at this location.

Former Brine Sludge Lagoon (now referred to as the "Closed RCRA Unit") - Precipitate sludge from Building 233 was mixed with brine to form slurry, which was pumped into this surface impoundment. The liquid component of the slurry was allowed to settle out then was pumped back to Building 233 to be purified and recycled. The lagoon was closed under a RCRA permit in 1984.

Chemfix Lagoon - The Chemfix Lagoon was constructed in 1976 north of the Brine Sludge Lagoon to conduct a test to determine whether the mercury in the brine sludge could be stabilized, thereby allowing the material to be managed as non-hazardous waste. The lagoon had the rough shape of a triangle with sides of about 60 ft by 80 ft by 80 ft. and was constructed with 8 foot high earthen berms. It was lined with two layers of 0.20 mil thick impermeable geosynthetic liners separated by a sand layer for an underdrain leachate collection system. Leachate collected by the system was pumped to the wastewater treatment system at Building 231. A demonstration run was conducted by Chemfix Technologies Inc. in 1976. Approximately 120,000 gallons of brine sludge (about 460 cubic yards) were treated and stored in the Chemfix lagoon over a four-day period. The process was never repeated and the lagoon was not used again.

In October 1981, LCP Chemicals, Inc., submitted a closure plan for the Chemfix lagoon to the NJDEP and reported that the treated material had the consistency of concrete. The closure strategy consisted of dewatering the lagoon, treating the wastewater in their waste treatment facility, and transferring the solid Chemfix contents, including liners and leachate collection system, to the Brine Sludge Lagoon.

The closure plan was approved by the NJDEP and the Chemfix lagoon materials were transferred to the brine sludge lagoon by September 1983. The Chemfix lagoon was backfilled, graded, seeded, and formally closed by the end of 1983 with NJDEP approval.

Former Sludge Roaster - A pilot sludge roaster unit was constructed south of the brine sludge lagoon in 1978, but the brine sludge material was processed through it only infrequently. By 1980, the final modifications to the sludge roaster were completed and the unit was brought back on line after LCP Chemicals, Inc., was issued a temporary air permit from the NJDEP. In 1985, the unit was dismantled and moved off Site, leaving only the concrete pad.

A number of additional structures are located on the LCP site, including:

- Building 220 – Shops and Service Building
- Building 221 – Lab and Locker Building
- Building 234 – Cooling Tower
- Building 250 – Warehouse
- Building 309 – Cooling Tower
- FRP Fabricating Shop

2.5.2 Tanks

A number of tanks are located on the site that were previously used to store mercury, chlorine, hydrochloric acid, brine, bleach, petroleum and other compounds. The onsite tanks were investigated as part of the Phase I and Phase II RI. The name, location, contents and condition of the tanks are detailed in Table 2-8.

2.6 LCP Waste Handling

2.6.1 Wastewater and Site Drainage

Industrial process water and stormwater flow from the LCP site during operations drained to the Arthur Kill. This drainage occurred historically via the former GAF site drainage system through hydraulic connections to South Branch Creek. After approximately 1976, the wastewater drainage was treated separately from the GAF site. The drainage in and around the LCP site was modified several times, and is described as follows:

Prior to 1947

Prior to 1947, before operations began at the LCP site, South Branch Creek was oriented in what was a relatively natural tidal stream channel that was relatively unimpacted by filling (Figures 2-2 through 2-4). The flow originated from the area located west and south of the GAF site production area and flowed eastward across the center of what would later become the LCP site to discharge to the Arthur Kill (Figure 2-21).

Surface water drainage in the wetlands located to the southwest of the LCP Site flowed into the Northern Off-Site Ditch, and followed a parallel alignment to the future LCP property line towards the southeast and onward to a series of mosquito ditches leading to the Arthur Kill. The remnants of ditches from the western side of the LCP Site and adjacent GAF property directed drainage into the Northern Off-Site Ditch. The Southern Off-Site Ditch runs parallel to the Northern Off-Site Ditch and collected drainage from the future Conoco bulk petroleum storage property, and discharges to the same series of Mosquito Ditches.

Comment [PJT34]: Ditch Report

1947 to 1951

Starting in 1947, South Branch Creek was diverted to an alignment that looped around the southern area of the future LCP production area prior to discharging to the Arthur Kill. The realignment was associated with the filling of the portion of the creek in what would become the production area of the LCP site. That same year the original creek was filled in. A primary treatment facility was constructed along the southerly loop of South Branch Creek on the LCP site as observed on the April 20, 1951 aerial photo (Figure 2-11).

The Northern Off-Site Ditch has been redirected to a culvert on the downstream end which appears to have directed flows in a northeast direction across the present day alignment of South Branch Creek. The alignment of the Southern Off-Site Ditch remains the same. The Southern Off-Site Ditch was placed in a culvert at its downstream end to re-direct flows in a direct eastward direction towards the Arthur Kill.

Comment [PJT35]: Ditch Report

1951 to 1966

The construction of the future LCP site began in approximately 1951. The chlorine operation began at the LCP site in 1955. By 1956, the core of the buildings required for the chlorine productions were present, including Buildings 220 and 230. The hydrogen processing facility started operation in 1959. The Brine Sludge Lagoon was reportedly constructed in 1962. Four years later, berms were present along the north and west side of the lagoon area.

~~The process wastewater from the mercury cell buildings drained to concrete floor trenches where it was collected in the northwest corner of each building. The process wastewater was reported to have been pumped to holding tanks and eventually pumped to the on-site wastewater treatment plant.~~

Comment [PJT36]: SC#3

The South Branch Creek channel continued to flow to the Arthur Kill from the southeastern portion of the GAF site, as described above, around the southern end of the LCP site, until 1966. During this time, wastewater in South Branch Creek and site drainage from the LCP and GAF sites were treated in the primary wastewater plant area located at the southern end of the South Branch Creek loop on the LCP site as observed on Figures 2-13, 2-14, 2-15 and Figure 2-21.

The process wastewater from the mercury cell buildings drained to concrete floor trenches where it was collected in the northwest corner of each building. The process wastewater was reported to have been pumped to holding tanks and eventually pumped to the on-site wastewater treatment plant.

Comment [PJT37]: Sc#3

1966 to 1971

South Branch Creek was relocated by 1966 into a covered channel (or "flume") located along the northern border of the LCP site (Figure 2-23). The primary WWTP located along the southern loop of South Branch Creek was apparently replaced at this time with a treatment area on the GAF site located several hundred feet upstream of the covered channel. The portion of South Branch Creek that previously looped around the southern side of the LCP site was replaced by a continuous concrete drainage trench.

1971 to 2003

In 1971, GAF ceased chlorine manufacturing operations. A year later, in 1972, LCP Chemicals, Inc. purchased the site from GAF and restarted manufacturing operations. Around the same time, the South Branch Creek channel located east of the railroad tracks was relocated into a newly created, narrow, man-made channel that discharged to the Arthur Kill approximately 950 feet south of the former South Branch Creek channel (Figure 2-25). This is the present alignment of the South Branch Creek channel.

A shallow concrete trench surrounding the process area was constructed in the 1970s (Eder, 1992) and was utilized to collect storm water and excess runoff from LCP Buildings 230 and 240. The flows in the trench were routed to a concrete sump south of Building 231 before being pumped to holding tanks outside Building 233. The water was pH adjusted, filtered, polished with carbon, and stored pending discharge to South Branch Creek under a NJPDES permit.

Wastewater treatment was previously reported to have occurred in a pond located along South Branch Creek immediately east of the electrical switchyard on the LCP site (Eder, January 1992) and as noted in an aerial photography analysis by USEPA (1999). Through the review of additional historic information, it is now known that this area was not used for treatment. This area is now known to have represented a wide segment of the ditch that was crossed by a bridge, hereinafter referred as the "Ditch Bridge Area" (Figure 2-14). The treatment area has been correctly located as previously discussed. The Ditch Bridge Area was reportedly excavated, backfilled, and covered with asphalt. The Ditch Bridge Area was still present in mid 1972 (LCP, July 21, 1972) and possibly only backfilled in 1982 (NJDEP, February 1982).

Around 1975-76, GAF constructed a new wastewater treatment facility on the GAF site. With the commencement of that wastewater treatment plant, wastewater flows from the LCP and GAF sites became separate.

The exposed portion of South Branch Creek, located immediately west of the railroad bridge, was blocked off with timber cribbing. This blockage of the creek likely occurred sometime after 1976 when the LCP site drainage was separated from that of the GAF site.

The chlor-alkali operations ceased in 1985. As discussed previously, the site continued to be used as a transfer terminal for other Hanlin products until 1994.

After 2003

Stormwater drainage from a large portion of the LCP site previously drained overland to a ditch that was located on the GAF site located immediately north of the LCP property line. Remedial construction activities at the GAF site including the construction of the shallow groundwater barrier and the site regrading have created a large undrained area in the northern and central areas of the LCP site.

Stormwater drainage from the LCP site is currently poorly defined. Large areas of the site are currently undrained including the aforementioned area along the GAF property line. In addition, much of the former LCP production area is currently undrained given the cessation of stormwater collection and treatment on the LCP site. Remaining areas of the site do drain to South Branch Creek and the unnamed ditch located immediately south of the LCP site. However, drainage from these areas is not well established given a lack of drainage structures and the nearly flat grades on the site. Accordingly, surface water that does drain to South Branch Creek and the unnamed ditch is characterized by undefined pathways and a distinct lack of high velocity flow. Ponding occurs in several areas of the site for long durations depending on rainfall intensity and duration.

2.6.2 Solid and Hazardous Waste Generation

It was reported that mercury-contaminated sludge, mercury vapors, spent lubricating oils, transformer oils, degreasing solvents, mercury contaminated process wastewater, spill wash down fluids and stormwater runoff were all waste products generated onsite (Eder, January, 1992).

The main source of mercury waste was the brine purification mud (otherwise known as, brine sludge) and associated process wastewater. In 1981, brine purification mud from mercury cell processes was listed as a hazardous waste by the EPA, No. K071. Associated wastewater treatment sludge was also listed as a hazardous waste, No. K106. The driving chemical behind the new classification was mercury.

A "typical" brine sludge composition as reported by LCP in 1975, was NaCl (20%), BaSO4 (50%), CaCO3 (15%), CaSO4 (15%), metal hydroxides (2%), dirt (2%), mercury (100-500 parts per million – 0.05%). Wastewater treatment sludge was also generated during chlorine production. In a 1975 LCP Preliminary Report on Brine Sludge, LCP estimated that 7.5 tons of sludge was generated everyday and that their current sludge stockpile was an estimated 11,000 cubic yards (Eder, 1992). Eder (1992) reported that up to 20 tons of sludge was generated per day.

Between 1980 and 1981, seven sludge samples were analyzed for selected inorganics (NJDEP, January 8, 1988). The samples showed that the sludge contained mercury concentrations ranging from 272 mg/kg to 4,574 mg/kg. Liquids filtered from the sludge contained mercury concentrations ranging from 40 µg/L to 2,520 µg/L.

A survey plan in a groundwater quality monitoring report by Geraghty & Miller (1982) shows that the brine sludge pile grew to a height of about 40 feet above the ground surface. An estimated 31,000 cubic yards of brine sludge was left in the lagoon at the time of its closure. The contents of the lagoon were dewatered, graded compacted and capped with clay and soil in 1984. This closure was permitted by NJDEP a New Jersey Pollution Discharge Elimination System (NJPDES) Discharge to Groundwater (DGW) Permit. The DGW permit is the New Jersey equivalent of a RCRA permit under USEPA's authorization of New Jersey's Hazardous Waste program.

Other potential sources of contamination included:

- ~~Historic~~ Anthropogenic fill placement by duPont, GAF and Conrail.
- Kuehne Chemical Company, which operated at the site from 1972 to 1981, allegedly dumped bleaches and other caustic materials into South Branch Creek on a daily basis.
- The Linde Division Hydrogen Plant, which received mercury-contaminated hydrogen gas from about 1957 to 1980, processed mercury on a daily basis.

Comment [PJT38]: ES#1

- Eder (September 1993) reported that small quantities of solvents used at the site for general cleaning and degreasing could have been released.
- Transformers were located behind Buildings 230, 240, and 231. (PCB contamination in the oil.)
- Storage tanks at the site used to store a number of different chemicals, including chlorine, sodium hypochlorite, sodium hydroxide, and methylene chloride (NJDEP, January 8, 1988).
- A 300 square-foot concrete drum storage pad with containment berms was located onsite. It was used to store motor oil, waste oil and other lubricants (Eder, 1993). During a NJDEP site inspection in December 1987, it was noted that there was stained soil in the area and vapors were detected.
- Active Water Jet discharged wash water from dirty tanks and pipes onto the site.

2.6.3 Environmental Compliance

2.6.3.1 Summary of Incidents and Enforcement Actions

In September of 1975, LCP was fined $10,000 for discharges of supernatant from the brine sludge lagoon into South Branch Creek in both 1971 and 1974, according to the NJDEP (July, 1991). On September 17, 1981 the NJDEP signed the Administrative Consent Order, which required LCP Chemicals, Inc. to cease use of the brine sludge lagoon by January 1, 1982, submit a closure plan for the sludge lagoon, submit a closure plan for the Chemfix lagoon, conduct air monitoring of the sludge pile and conduct groundwater, surface water, soil and sediment sampling sessions.

By late 1984 both sludge lagoons were closed. Air monitoring of the sludge pile took place on June 4, 1981 (RECON, 1981). Limited groundwater, surface water, soil, and sediment sampling were taken by Geraghty and Miller (1982).

The NJDEP issued an Order dated May 4, 1982 to cease the November 5, 1981 violation of N.J.A.C. 27-8.3(e)2 resulting from a ruptured muffler plate on the sludge roaster, which subsequently allowed mercury emissions to vent through for unpermitted roasting sessions. The sludge roaster was abandoned due to “bugs” in 1981. In a June 4, 1982 letter the NJDEP denied LCP’s Hazardous Waste Facility Permit Application due to several deficiencies in the sludge roasting system. LCP responded with a letter promising to fix the issues with the brine stabilization process.

The EPA issued a Complaint/Compliance Order dated August 1982 for lack of freeboard in a surface impoundment (otherwise known as the brine sludge lagoon). LCP was also cited for lack of waste analysis plan, not maintaining a scheduled inspection period, and a lack of a contingency plan. The freeboard penalty held a $1,000 fine; however, the other violations were corrected, thus a fine was avoided.

One year later in 1983 the NJDEP issued two “Notice of Violations”. One was for failure to submit a RCRA Treatment, Storage, or Disposal Facility Report. A report was submitted shortly after and so a penalty was avoided. The second was for failure to establish financial assurance for closure and post-closure monitoring of the brine sludge lagoon and to demonstrate financial responsibility for claims. LCP stated that the NJDEP Division of Waste Management now had copies of the necessary documents and that the matter was resolved.

The NJDEP issued an Administrative Order, dated February 11, 1985, requiring that LCP maintain documentation of the job title for each position at the facility related to hazardous management, the name of the employee that filled each job, security of roll-off containers with hazardous waste and to develop an evacuation procedure for employees. LCP corrected the problems and was issued a $900 fine.

2.6.3.2 Summary of Spills and Releases

The following spills/releases are documented by the EPA and NJDEP.

- In October 1972 and February 7, 1974, the NJDEP reportedly observed lagoon overflows into South Branch Creek, quantities and responses unknown. As for LCP, they acknowledged both discharges in September 1975 and were levied a fine by NJDEP of $5,000 for each occurrence (NJDEP, July 1991).
- June 25, 1975 – During a recycle pump failure, nine hours worth of discharge from the brine sludge lagoon spilled into South Branch Creek (LCP, July 27, 1975).
- August 15, 1979 – A salt blockage in a saturator caused an overflow of mercury contaminated brine (LCP, August 20, 1979). A sample of the overflow was taken by LCP and showed a concentration of 8.6 parts per million of TDS.
- In early 1981, a former employee who worked there from '72 to '80 stated he would sometimes analyze effluent water being discharged into South Branch Creek (NJDEP, October 7, 1981). It was noted that one specific time this former employee measured mercury concentrations of eight to ten times greater than the maximum allowances.
- October 7, 1981 – The NJDEP cited the Kuehne Chemical Company for discharging caustic material into the creek (NJDEP, October 7, 1981). Kuehne refused to accept charges and subpoenaed the NJDEP twenty days later for depositions. The outcome is unknown.
- The following spill documentation was noted in a RCRA Facility Assessment for LCP, NJDEP Site Inspection Reports regarding several spills near the 500,000 gallon brine tank (NJDEP January 8, 1988):
  - The first of the documented spills was in September 1980 when an unspecified amount of brine sludge was noted on the gravel near the tank. The second was also in 1980, one month later. While transferring brine sludge from the 500,000 gallon tank to the lagoon some was spilled. (Front end loader and dump trucks were used for this process). LCP stated that the sludge would be flushed to the sump next to the tank.
  - In January 1981, an overhead pipe appeared to have a leak, which dumped wash water from cells onto unpaved ground. Another pipe was observed to have had a leak in 1981. However, this pipe was filled with hydrochloric acid. The final spill located by the 500,000 gallon tank was noted in April 1982. It involved a spill of sodium sulfide crystals.
- Though that was the final spill documented by the tank, it was not the last documented spill on site. Other NJDEP Site Inspection reports cite brine sludge spills/ leaks (NJDEP, January 8, 1988). Three examples were found and are listed below, all in 1981.
  - In January 1981, a former employee who worked on site from 1972 to 1980 stated that brine sludge was removed from the lagoon and spread out on the ground between Building 231 and the railroad tracks (NJDEP January 25, 1981). It was noted that to the former employee's knowledge this only happened one time in either 1973 or 1974.
  - In October 1981, a 1 ft by 15 ft spill of brine sludge slurry leaked from overhead piping between the 500,000 gallon tank and the sludge lagoon. The exact location is not well documented, but noted on the NJDEP sketch maps (NJDEP November 19, 1981).
  - In November of 1981, an overhead line was leaking, resulting in a 30 ft by 125 ft spill along Avenue B railroad tracks.

The information on spills/releases at the LCP site was one factor used to develop the original RI work plan for the site (URS, 2001).

2.6.3.3 LCP Environmental Upgrades

LCP met with the NJDEP by 1975 to investigate waste disposal options for brine sludge, wastewater and the estimated 11,000 cubic yards of sludge material stockpiled in the brine sludge lagoon. LCP Chemicals, Inc. informed the NJDEP that off-site disposal options were too expensive and elected to begin pilot testing a more cost effective stabilization process developed by Chemfix Technologies, Inc.

As required for stabilization, an auxiliary surface impoundment was constructed onsite, the Chemfix lagoon. Its process treated about 120,000 gallons (or 460 cubic yards) of brine sludge over its 4 days existence in 1976. The results were apparently questionable, so the Chemfix process was never continued.

LCP Chemicals, Inc. also tested a sludge roasting process. This stabilization method would volatilize and capture mercury from steam dried brine sludge. LCP received favorable results during bench testing. A pilot sludge roaster unit was constructed south of the brine sludge lagoon in 1978. Throughout the lifespan of the sludge roaster, it was only used infrequently as it required constant "debugging, modification, and repair". Finally in 1980, the sludge roaster was up and running. LCP was issued a temporary air permit from the NJDEP, although a final permit was never issued. In December 1980, LCP Chemicals, Inc. and the NJDEP agreed that the brine sludge lagoon required closure and would formalize the process through an Administrative Consent Order.

In 1982, LCP ceased plant operations during the lagoon closure as a protective measure for plant workers' health and safety, reportedly at the orders of the NJDEP and EPA. A year later the Chemfix lagoon was closed (all materials were transferred to the brine sludge lagoon). The brine sludge lagoon was closed by November 1984 with NJDEP approval. In accordance with law, the lagoon was reportedly dewatered, compacted, covered with a two foot thick clay cap, and then covered again with soil and seeded as part of a RCRA permit for the Closed Brine Sludge Lagoon). This area is now called the closed RCRA Unit. In June 1984, LCP submitted a facility closure plan to the NJDEP. The EPA (1984) stated that LCP Chemicals, Inc. had planned to begin chlor-alkali manufacturing facility operations again in late 1984, but decided to cease all plant production instead. By August 1985, all plant productions were stopped. The facility was dismantled; the equipment was shipped to other LCP facilities along the east coast. The facility was still being used as a storage and transfer station for chlorine-related products, including, sodium hydroxide, potassium hydroxide, methylene chloride, and hydrochloric acid.

The Hanlin Group, Inc. filed for bankruptcy under the Chapter 11 of the U.S. bankruptcy code in July 1991. By April 1994, Hanlin sold all of its company assets and ceased all operations. After a site visit in August 1994, the EPA confirmed that the facility was no longer functional and that all employees were expected off the site by the end of August 1994. On November 10, 1998 the site property was formally abandoned by the bankruptcy trustee by order of the Federal Bankruptcy Court.

2.6.3.4 Environmental Permits

In 1975, a NJPDES - Discharge to Surface Water (DSW) permit was granted to LCP for discharge of treated wastewater.

In August 1974, Kuehne Chemical Company submitted a New Jersey Pollutant Discharge Elimination System (NJPDES) permit application (No. 0027707). It was not until August 1980 that Kuehne received a permit for discharge of cooling water only. One year later, the NJDEP alleged that Kuehne was illegally dumping caustic chemicals. A Notice of Civil Administrative Penalty Assessment was issued to Kuehne. The notice states that a pipe was observed during an NJDEP site visit on January 26, 1981 "connected to the outfall in such a manner as to allow for a physical conduit for the passage of pollutants to the waters of the State." The connection was removed the next day on a follow-up visit by the NJDEP. The notice also stated that the Kuehne operations had ceased and vacated the site on the next day.

A NJPDES-DGW permit (No. NJ0077038) renewal was issued to LCP Chemicals – New Jersey on June 11, 1993 with respect to the RCRA closure of the former brine sludge lagoon. This permit is the equivalent of a RCRA Post Closure permit under the USEPA authorization of New Jersey's Hazardous Waste program.

2.6.3.5 Interim Remedial Actions

Comment [PJT39]: SC#62

Interim Remedial Measure of Former Mercury Cell Buildings

An Interim Removal Action (IRA) was performed by ISP-ESI in the former mercury cell buildings and elsewhere in the production areas on site in 2001 and 2002. The IRA included the removal and disposal of former process equipment, laboratory samples and chemicals, visible elemental mercury that was present at that time, loose asbestos, and miscellaneous debris. Further detail of the IRA is provided in the Interim Removal Action Final Report, prepared by URS dated April 16, 2001.

Proposed Interim Action for South Branch Creek

The conceptual design for an Interim Action (IA) was proposed by ISP-ESI on June 15, 2007, in response to the presence of elevated mercury and other contaminants in sediment and low marsh soils associated with South Branch Creek. The IA was intended to arrest the potential migration of the contaminated low marsh soils and sediments from the site. Implementation of the proposed IA was rejected in a letter from Ms. Carole Petersen of USEPA dated August 8, 2007.

2.7 Regional Geologic Conditions

The area of the site is located on the eastern edge of the Newark Basin, which is located in the Triassic lowlands subprovince of the Piedmont Plateau physiographic province of New Jersey. The Newark Basin contains approximately 15,000 to 20,000 feet of late Triassic and Early Jurassic (135 to 225 million years ago) continental derived sediments, including shales, siltstones, sandstones, and conglomerates. Interbedded among these sediments are three major extrusive basalt flows and one major diabase intrusive, representing volcanic episodes during the early Jurassic period (Olsen, 1980). A thin mantle of Pleistocene glacial and Recent deposits covers much of the Newark Basin rocks today. These units are described in additional detail in the following subsections.

2.7.1 Surficial Geology

Anthropogenic Fill

Anthropogenic filling of the region began in the 1600s as soon as European settlement occurred. Larger scale filling occurred in the late nineteenth and early twentieth century and was largely associated with industrial and transportation infrastructure development. Filling continued in the area to support the Newark Airport and the Port Newark and Port Elizabeth marine terminals until around 1970. A large percentage of the former tidal marshes in the area have now been filled. The emplaced fill materials include sand, gravel, silt, clay, and rock, as well as various man-made materials like cinders, ash, brick, concrete, wood, slag, glass, and trash (Stanford, 2002). The fill is most often less than 10 feet thick but may be thicker in road and rail beds.

Tidal Marsh Deposits

Recent sedimentation in the region includes alluvium (river), tidal marsh, and eolian (windblown) deposits. The alluvium includes floodplain, channel, and backswamp deposits, which include sands, silts and minor gravels and clays with sorting that varies from well to poor, depending on the specific depositional environment.

Tidal marsh material, underlying the anthropogenic fill, is present beneath much of lowland areas that comprise the eastern portion of Linden bordering the Arthur Kill and other coastal and tidal water bodies in New Jersey. Tidal marshes are flat, low lying coastal areas that become regularly inundated during high tide periods. Sediments that have formed in the marsh areas in the vicinity of the site include organic rich silts and clays, as well as peat. The peat typically consists of a horizontal layer of roots of salt tolerant plants in various stages of biological decomposition. The peat occurs in varying states of weathering and consolidation. Peat typically weathers to organic silt and clay. Thus, it is not unusual to encounter the organic silt and clay beneath peat at the base of the tidal marsh deposits. Fine to coarse grained, well sorted sand sediment that formed as the result of eolian (e.g., wind-blown) deposition may be interbedded with the organic clay and peat (Stanford, 2002).

Glacial Till

The Linden area is situated near the glacial terminus and was covered with a relatively thin layer of glacial ice during the last (Wisconsin) ice advance. During this time, much of New Jersey to the west and northwest was covered with a thicker ice layer, estimated to have been at least one mile thick. As a result of a lighter overburden of ice, glacial deposits near the glacial terminus are considerably less dense and less compacted than those to the west and northwest. As the glacier melted, numerous glacial sediments (tills and moraines) were deposited over much of New Jersey. Ground moraine deposits are typically poorly sorted and not stratified. Much of the area north of the terminal moraine, including Linden, New Jersey, is covered by a sheet of ground moraine more commonly called till.

The Rahway Till found in and around the LCP site varies from silty sand to sandy clayey silt. The till contains some to many pebbles, cobbles and a few boulders. The till can be as thick as 90 feet but is usually less than 20 feet in thickness (Stanford, 2002).

2.7.2 Bedrock Geology

The unconsolidated deposits are underlain by Triassic-Jurassic aged sedimentary rock. The rocks formed following the close of the Paleozoic Era (225 million years ago), when compressive forces that formed the Appalachian Mountains relaxed, and extensional forces associated with the rifting and spreading of the Atlantic Ocean began. A series of isolated troughs called grabens formed east of the Appalachian Chain extending from Nova Scotia to North Carolina. As spreading of the ocean progressed, large blocks of crust down-faulted along extensional fault zones. Synchronous with the down faulting, large quantities of continental sediments produced from the erosion of the Appalachian Mountains were deposited in these troughs. The continued accumulation of sediments overloaded the troughs and contributed to their subsidence. This sinking effect allowed for the thick accumulation of Triassic sediments that exist in the Newark Basin. During the early Jurassic Period (180 million years ago), as rifting continued, faults in the area became progressively deeper and intersected the earth's mantle. Consequently, volcanism occurred in the form of extrusive basalt flows over parts of the basin, forming the Watchung Mountains of New Jersey. Three separate episodes of basalt flows occurred, interrupted by periods of continental sedimentation (Faust, 1975).

Nine formations comprising the Newark Supergroup resulted from the lithification of these basin sediments and volcanic flows (Olsen, 1980). The formations from oldest to youngest are as follows: the Stockton, the Lockatong, the Passaic, the Orange Mountain Basalt, the Feltsville, the Preakness Basalt, the Towaco, the Hook Mountain Basalt, and the Boonton. Contemporaneous with the basalt flow events, intrusive sills and feeder dikes formed the Palisades Diabase. The diabase unit is not classified as part of the Supergroup, despite its stratigraphic presence within the Newark Basin formations.

Three of the nine Newark Super group formations are present below the site, including the Stockton, the Lockatong, and the Passaic. The Stockton and the Lockatong formations were not encountered during the investigation, as they are present only at great depth; therefore, they will not be discussed further in

this report. The Passaic formation was observed during the investigation and is discussed below in greater detail.

- **Passaic Formation (JTp):** According to Olsen (1980), the Passaic formation, representing flood bank and fluvial deposits, reaches a thickness of approximately 20,000 feet. This unit consists of reddish brown mudstone (a non fissile equivalent of shale), siltstone, and sandstone interbedded with conglomeratic sandstones along the basin margins.
- **Lockatong Formation (Tl):** The Lockatong Formation, which conformably underlies the Passaic Formation, is approximately 3,800 feet thick in west central New Jersey and thins laterally to the northeast and southwest. This formation was deposited as a large lacustrine lens composed of gray and black shales with argillite, flagstone and impure limestone layers (Wolff, 1977). Regionally, the lower members of the Lockatong Formation are intruded by the Palisades diabase as a sill.
- **Stockton Formation (Tl):** The Stockton formation consists primarily of lacustrine sediments similar to the overlying Lockatong formation. The lower Stockton represents mostly fluvial deposits. The Stockton Formation consists of sandstone, siltstone, arkose conglomerate and mudstone with color ranging from a light brown to dark brown-purple-red. The formation has a maximum thickness of 6,000 feet.

One of the nine Supergroup formations, the Passaic Formation (JTp), is present below the Site. In this area, the Passaic Formation is comprised of two facies: the sand and siltstone facies to the northwest and mudstone facies to the southeast of the area. The Linden area is underlain by the mudstone facies. Typically these sediments form cyclic sequences of cross-bedded units that grade upward from coarser to finer grain size. The dominant facies in the formation are siltstone (60%) and mudstone (40%) with the coarser sandstones and conglomerates comprising only a small fraction of the total percentage. Generally, the overall sequence of the Lower Passaic formation becomes finer from bottom to top with more mudstone and less siltstone going upward (Olsen, 1996). The Upper Passaic formation displays the reverse trend, with increasingly frequent silt and fine sand beds and less frequent gray and black mudstones progressively towards the top of the unit.

The upper shale (mudstone) of the Passaic formation is relatively soft and easily weathered. At surface exposures this rock is intensely and indiscriminately fractured on a small scale (1 to 5 mm) and obtains a hackly to chippy appearance. Unlike the siltstone layers of the Passaic formation, this rock lacks well-developed bedding planes and the regional joint pattern set (Houghton, 1986).

With increasing depth, the shale grades vertically into hard, massively bedded siltstones. The regional joint system is very prominent in these rocks and the bedding planes are very distinctive. The dominant strike of the Passaic Formation is reported to be N50°E with the beds dipping gently to the northwest between 9° and 12°. The shale also has a prominent set of vertical fractures (joints) striking N45°E and a less prominent second set of near vertical fractures striking N75°W. Regionally, this rock outcrops several miles west of the site where it exhibits more resistance to weathering and retains its characteristic features.

2.8 Regional Hydrogeologic Conditions

The Passaic and Lockatong Formations form the widespread Brunswick aquifer which conducts water in the region eastward to discharge to the Arthur Kill. Groundwater is found predominantly in the fracture planes within this rock and flow is directionally controlled by the fracture orientation. Permeability and storage are also controlled by fractures in the mudstone and siltstone facies though not necessarily to the same degree in the sandstone facies (Michalski, 1996). Hydraulic conductivities in the Brunswick Aquifer have been found to range from 6.9×10^{-7} cm/sec to 7.6×10^{-3} cm/sec (New Jersey Geological Survey, 2004; Michalski, *et al.*, 1992).

2.8.1 Groundwater Use

Comment [PJT40]: SC#5

Due to the proximity of the Arthur Kill and other tidal waters to Linden, groundwater within this region, including the Passaic bedrock aquifer(s), is typically saline (Anderson, 1968). Since this water exceeds the New Jersey Safe Drinking Standards for naturally occurring salinity, the area is unsuitable for public water supply wells.

Regionally, brackish groundwater concentrations tend to diminish gradually with increasing distance from the source waters. Further inland from the Arthur Kill and within five miles of the site, the Passaic formation is extensively developed as the primary water supply source. The depths of these wells range from 75 to 570 feet and yield volumes of water between 100 and 400 gallons per minute (see Table 2-9). Locally occurring unconsolidated aquifers have also been tapped for water supply within this region. Relatively fewer in number, these aquifer(s) serve as the primary public water source for the Rahway area. Also, some shallow supply wells screened in the Quaternary sand and gravel, and yielding up to 300 gallons of water per minute, are used as a source of industrial waters.

Six (6) public community water supply wells (Figure 2-26), all upgradient of the site, are located within a four to five (4 to 5) mile radius of the site. As shown in Table 2-9, the depths of these wells typically range from 200 to 500 feet bgs. The pumping rates for these wells are not known but the capacity for wells range from 200 to 450 gallons per minute (gpm). Each of these wells is owned and operated by the New Jersey American Water and are located approximately four miles to the northwest and upgradient of the Arthur Kill. New Jersey American Water is the primary supplier of potable water to the Linden, New Jersey area. At the site, all potable water is provided by the New Jersey American Water.

2.8.2 Groundwater Classification

Comment [PJT41]: GC#2, SC#5

The "default" groundwater quality classification in New Jersey is Class II-A unless otherwise classified as Classes I, II-B or III. Per N.J.A.C. 7:9C-1.5(e)1, "The primary designated use for Class II-A ground water shall be potable water and conversion (through conventional water supply treatment, mixing or other similar technique) to potable water." Therefore, most groundwater in New Jersey is regulated for potential potable supply."

Notwithstanding the Class II-A classification, there are specific areas in the region and at the site in which groundwater is not suitable for potable uses. Some of these have been formally reclassified to Class III-B pursuant to N.J.A.C. 7:9C-1.5(f)4 in recognition of the naturally-occurring saline condition of the groundwater. Other areas that would not meet the Class III-B reclassification requirements nevertheless are unlikely to be developed for potable water supply given other regulatory constraints. These conditions are described as follows:

Overburden Water-Bearing Zone

While naturally-occurring saline conditions are observed in areas of the overburden water-bearing zone in very close proximity to tidal surface water bodies, the areal distribution of this condition is insufficient for the reclassification of the entire zone at the LCP site. However, at least two (2) separate New Jersey regulations would prevent the overburden water-bearing zone from ever being used at the site as a potable or non-potable water supply through the installation of Category 1 or 2 wells[3].

N.J.A.C. 7:9D (Well Construction and Maintenance; Sealing of Abandoned Wells) states that for potable water supplies installed in unconsolidated formations:

[3] Per N.J.A.C. 7:9D-2.1, Category 1 Potable Water Supply Wells are defined as "domestic, non-public, public community supply, and public non-community wells" and Category 2 Non-Potable Water Supply Wells are defined as "fire protection, irrigation, test, industrial, livestock, open loop geothermal and injection or recharge wells."

> "All well casing shall be no less than four inches in diameter and no less than 50 feet in depth" (N.J.A.C. 7:9D-2.3(a)3i.); and "All wells shall have a minimum length of 50 feet of grout seal extending from the top of the gravel pack or top of the well screen to grade." (N.J.A.C. 7:9D-2.3(a)3iii.)

By application of this regulatory restriction, a water supply well can never be installed within the overburden water-bearing zone at the site since it is required to be entirely sealed off by impermeable casing material. Geologic information presented in Section 5.1 reveals that the depth to the bedrock beneath the site typically ranges between 35 and 50 feet below ground surface. This depth is short of the minimum 50 foot casing and grout requirement specified in N.J.A.C. 7:9D such that it would be physically impossible to install a well in the overburden without violating the 50-foot casing requirement.

In addition to this well construction restriction, N.J.A.C. 7.7E (Coastal Zone Management) restricts groundwater use in areas where coastal resources could be negatively impacted by pumping. With regard to groundwater use, this particular regulation states:

> "Coastal development shall demonstrate, to the maximum extent practicable, that the anticipated groundwater withdrawal demand of the development, alone and in conjunction with other groundwater diversions proposed or existing in the region, will not cause salinity intrusions into the groundwaters of the zone, will not degrade groundwater quality, will not significantly lower the water table or piezometric surface, or significantly decrease the base flow of adjacent water sources." (N.J.A.C. 7.7E-8.6(b))

It is likely that groundwater withdrawals from the overburden water-bearing zone would cause substantial reduction of the water table surface that would potentially cause saltwater intrusion. Thus, approval for the use of overburden groundwater as a drinking water source would not be possible under N.J.A.C. 7.7E.

Nevertheless, despite the actual use or potential use of the resource, the regulatory standards for Class II-A are the applicable standards for the overburden water bearing zone

Bedrock Water-Bearing Zone

The bedrock water-bearing zone at the LCP Site has formally been reclassified as Class III-B as described in the document titled "Request for Class III-B Aquifer Designation, LCP Chemicals Inc. Superfund Site and ISP-ESI Linden Site, Linden, New Jersey" (Brown and Caldwell, April 2008) and as approved by a letter from Messrs Frank Faranca and Ian R. Curtis of NJDEP dated February 27, 2009.

The groundwater quality within the bedrock water-bearing zone was characterized through the sampling of monitoring wells installed and located on both the LCP site and the adjacent GAF site. The water quality data include the results from chloride and total dissolved solids (TDS) analyses in addition to numerous other analytical parameters. Chloride and TDS are the two parameters specified in N.J.A.C. 7:9C as the parameters used to establish Class III-B classification. N.J.A.C. 7:9C states that:

> "Class III-B ground water consists of all geologic formations or units which contain ground water having natural concentrations or regional concentrations (through the action of salt-water intrusion) exceeding 3,000 mg/l Chloride or 5,000 mg/l Total Dissolved Solids, or where the natural quality of ground water is otherwise not suitable for conversion to potable uses."

The chloride and TDS results for the LCP and GAF sites exceeded the Class III-B criterion of 3,000 mg/L for chloride and the 5,000 mg/L criterion for TDS for all tested bedrock wells on the LCP site. These data demonstrated that the groundwater quality conditions in the bedrock water-bearing zone are impacted as a result of naturally-occurring, salt water intrusion from the nearby tidally influenced surface water bodies.

2.9 Ecologic Conditions

No endangered, threatened, or rare (ETR) species or significant ecological communities have been found within the LCP site's boundaries, nor are there any records at NJDEP of rare wildlife or plant species or ecological communities within the site (NJDEP has reported that foraging habitat for several threatened bird species lies within ¼ mile of the site [black- and yellow-crowned night herons and colonial water birds], but none of these species have actually been observed). Similarly, NYSDEC indicated that two endangered bird species are located within ¼ of the site (yellow-crowned night heron and pied-billed grebe). South Branch Creek represents low-grade habitat for these species and nesting on site is therefore not expected. There is also no suitable habitat in the site area for the two species listed for Union County on the Federal Comprehensive List of Endangered and Threatened species provided on the USFWS's website (one turtle, one bat).

Overall, the flora and fauna found on the site are species typically found in heavily industrialized areas within intertidal marsh ecosystems. Vegetative species found within the site are very common to highly disturbed areas and possess no Federal or New Jersey State protection. Six terrestrial mammals and two terrestrial reptile/amphibian species have been reported. No aquatic mammals have been reported.

South Branch Creek and the Arthur Kill are National Wetlands Inventory (NWI)-mapped wetlands. There are no State designated wetlands on site. A wetlands delineation was performed along South Branch Creek for which a Letter of Interpretation was obtained by NJDEP (Figure 5-16). The border of the nearest NJDEP-mapped wetland is located to the south of the site, approximately 500 feet from the outlet of South Branch Creek to the Arthur Kill.

Pralls Island, located in the Arthur Kill directly opposite to the LCP site off the shoreline of Staten Island, contains areas of New York State Department of Environmental Conservation-mapped Tidal Wetlands. Classified tidal wetlands include areas identified as Intertidal Marsh, High Marsh, and Formerly Connected. The locations of these wetlands are presented in Figure 2-X. Please refer to the Habitat Assessment report (Appendix F) for additional details.

Comment [PJT42]: SC#6 – Figurre Added

2.10 Regional Studies

As stated previously, most of the region was highly industrial and consists of land that has been created through the filling of tidal wetlands. The Arthur Kill is a large navigable, tidal straight that is tidally influenced from the New York Harbor and the Atlantic Ocean. Likewise, the Rahway River to the south is a tidally influenced tributary of the Arthur Kill traveling through an industrial area. Background contaminant conditions and contributions to the sediments from many sources are widespread. There are numerous NJDEP-contaminated sites in the region, in addition to the LCP site, many of which have the highest remedial level designations of "C3" and "D," indicating high levels of multiple contaminants that may be impacting surface and groundwater. Additionally, there are a number of sites within the Newark Bay complex with extremely high mercury levels that may influence levels in Arthur Kill (NJDEP 2001). In addition, the New Jersey Turnpike, completed in 1954, crosses Piles Creek west of the GAF site. The Turnpike is a regional source of contaminants typical of road runoff, such as heavy metals (particularly lead), BOD/COD, nutrients, oil and grease, PAHs, pesticides, herbicides, and PCBs, as well as of contaminants released through spills and accidents on the roadways.

Numerous studies have addressed specific contaminants and their fate and transport in the New York/ New Jersey Harbor system. Many of these are catalogued and distributed by several regional organizations. Key data from these organization's databases are presented on Figures 2-27 and 2-28. Additional information regarding the regional studies is described below.

2.10.1 Contamination Assessment & Reduction Project (CARP)

Contamination Assessment & Reduction Project (CARP) is a coalition of harbor partners from federal, state and non-governmental branches, headed up by the New York State Department of Environmental Conservation (NYSDEC). The purpose of the project is to find solutions for the harbor's dredged materials. Its main objectives are identifying and quantifying the sources of contamination, establishing baseline levels of contaminants of concern in the water, sediment and fish tissue, and predicting future conditions (CARP, 2008).

CARP uses mathematical modeling to characterize the dioxins/ furans, PAHs, pesticides, and metals present in the harbor system. Their models include point and non-point source loading inputs, estuarine hydrodynamics and sediment transport, contaminant fate and transport, bioaccumulation and toxicity (CARP, 2008). The results used for these models are stored in a database. The database not only stores CARP data but also a range of other data sources, including the EPA's REMAP project.

The EPA's Regional Environmental Monitoring and Assessment Program, otherwise known as REMAP, is a regional study, which obtains information on the New York/ New Jersey Harbor. It was created to "answer ecological questions on a regional scale" (EPA, 2007). The project obtains sediment, water and benthic samples. These results can be found in the CARP database along with several other projects.

In Figure 2-27 and 2-28 CARP's results for mercury and dioxin in the estuary sediment have been plotted. Each figure shows a large number of samples collected in the Lower Passaic region due to its industrial nature, which is a useful comparison for the LCP region.

2.10.2 National Oceanic and Atmospheric Administration (NOAA)

National Status and Trends Program run by the National Oceanic and Atmospheric Administration (NOAA) also monitors the Hudson-Raritan Estuary. The concentrations of contaminants and the biological responses to said contaminants in this area have been compared to other sites around the United States. This study specifically targets point and non-point sources and characterizes the contaminants of concern for each.

The NOAA study was used to determine the current status of the NY/NJ Harbor estuary system. Their samples were taken north of the LCP site, mostly in the Newark Bay and in the lower Passaic River, Figure 2-27 and 2-28. These results were then compared with the CARP data and the LCP data.

2.10.3 Old Place Creek

Old Place Creek was selected to serve as a reference stream. Old Place Creek is a tidal creek consisting of salt marshes and an adjacent successional southern hardwood forest, and is located in Staten Island, New York, on the eastern side of the Arthur Kill (Figure 2-20). The area is located immediately north of the Goethals's Bridge and is surrounded by heavy industrial development. This creek is similar in many respects to SBC, including the width and depth, and provides a tool for evaluation of SBC and other regional data.

Samples of sediment, surface water, and biota were collected in Old Place Creek by BC on behalf of ISP-ESI contemporaneously with the Phase II RI in fall 2008. The purpose of this effort was to characterize regional background conditions. Samples were analyzed for TCL/TAL analytes as well as total and methyl mercury, and Dioxins/Furans. The results of the study of Old Place Creek are presented in Appendix N.

Section 3

RI Field Investigation Methods and Procedures

The RI field investigation was performed at the LCP Chemicals Inc. Superfund site (LCP site) in two major phases between July 2001 and May 2008. A summary of the field investigation methods and procures for both are presented below.

Phase I RI Field Investigation

The Phase I RI field investigation was conducted between July 2001 and April 2002 and included the collection and analysis of samples from soil, groundwater, surface water, and sediment, at the locations as shown on Figure 3-1. In addition, data were collected to provide geologic, hydrologic, and hydrogeologic interpretation of the site.

The Phase I RI field investigation was performed by Brown and Caldwell and their subcontractors. In addition, Quantitative Environmental Analysis, LLC (QEA) performed the sediment and surface water sample collection and associated data evaluation. Technical oversight was provided in the field by USEPA and/or their oversight contractor, TAMS Consultants, Inc.

The work that was performed during the Phase I RI field investigation is described in the USEPA approved documents listed in Section 1.4.1.

Phase II RI Field Investigation

The Phase II RI field investigation was performed at the LCP site from August 2006 to June 2007. Additional samples were also collected in May 2008. The Phase II field investigation included the collection and analysis of samples from soil, soil vapor, groundwater, surface water, sediment, and biota at locations shown on Figure 3-2. Other work included various hydrogeologic testing, a habitat assessment, and a wetland assessment. The Phase II RI field investigation was performed by Brown and Caldwell and their subcontractors. Continuous technical oversight was provided in the field by USEPA's oversight contractor, CDM.

The scope, methods, and procedures that were used during the Phase II RI at the LCP Chemicals, Inc. Superfund Site are described in a series of USEPA approved documents listed in Section 1.4.

The scope of the RI field investigation is described in Sections 3.2 through 3.8. The specific methods that were employed in the field investigation are described in the Field Operations Plan and associated addenda that are presented in Appendix B.

Off-Site Ditch Investigation

Comment [PJT43]: Ditch Report

The Off-Site Ditch field investigation was performed during August 2011 within the two drainage ditches located directly south of the LCP Site, as described in section 1.4.3. The investigation included the collection and analyses of samples from surface water and sediment at locations presented in Figure 3-3. The investigation also included the measurement of physical parameters such as water depth, sediment thickness, channel width, depth, and flow velocity in the two ditches. The Off-Site Ditch investigation was performed by Brown and Caldwell and their subcontractors. Technical field oversight was provided by USEPA's oversight contractor, CDM.

3.1 Areas of Concern

A number of Areas of Concern (AOCs) were identified during the development of the initial (Phase I) RI Work Plan in 2000-2001 to focus the sampling activities during the initial (Phase I) RI. Selection of AOCs was based upon knowledge of former site activities and data from prior site investigations. The estimated boundaries of the AOCs are presented on Figure 3-1 which have been adapted from the document titled "Final Sampling and Analysis Plan, Field Operations Plan, Part I", (URS, April 12, 2001). The following AOCs were identified:

- East Berm of the Brine Sludge Lagoon
- Leaking Pipe – Building 231 Area
- Chemfix Lagoon
- Former Sludge Roaster
- Building 230 and Building 240 – Mercury Cell Rooms
- Building 231 – Purasiv Area
- Former Transformer Area Building 231, Building 230, and Building 240
- 500K Tank
- Bullet Tanks
- Salt Silo No. 4
- Drum Storage Pad
- Concrete Drainage Pad
- Former Waste Water Treatment Area
- 12,000 Gallon Polyethylene Tank (12K)
- South Branch Creek
- Areas of Suspected Past Releases
- Areas Requiring Risk Assessment
- Potentially Contaminated Non-Process Areas
- ~~Historic~~ Anthropogenic fill
- Groundwater

Comment [PJT44]: ES#1

The Phase II RI technical objectives, as described in Section 1.4.2 were developed to address specific, site-wide characterization issues, without regard to individual AOCs. While useful for the development of the initial (Phase I) work plan, AOCs were not utilized in the development of the Phase II RI Work Plan documents. Furthermore, AOCs are not useful in the evaluation of contaminant nature and extent and have not been utilized in the discussion that is presented, herein, in Section 6.

3.2 Hydrogeologic Investigations

Various tasks were performed to obtain information required for hydrogeologic characterization of the site. These included the drilling of stratigraphic borings, the drilling and construction of monitoring wells, and the sampling, testing and collection of additional data from the wells. These tasks are described in the following sections.

3.2.1 Stratigraphic Borings

Deep soil borings were performed during the Phase I RI field investigation for the purpose of evaluating subsurface stratigraphic conditions. Three of these borings were advanced into the glacial till to depths of approximately 25 feet. Four borings were drilled to the top of the Passaic formation bedrock. Split

barrel soil samples were collected from the borings for the purpose of visual classification of the soils by a qualified geologist. Rock core samples were not collected from the borings. The borings were grouted to the surface upon completion. The procedures for drilling and sampling in the stratigraphic borings are described in Section 2.2 of the Field Operations Plan, Field Methods (Appendix B).

3.2.2 Monitoring Wells

A network of 31 groundwater monitoring wells currently exists at the site. Most of these were installed as part of the Phase I and Phase II RI field investigations. In addition, some of the existing, previously installed monitoring wells were utilized for the RI. Older, existing wells that did not meet a minimum construction standard, however, were decommissioned.

The monitoring wells were used for the collection and analysis of groundwater quality samples, the determination of groundwater elevations, and to perform in-situ hydraulic conductivity testing. Soil samples collected from the well boreholes allowed visual classification of the soils by a qualified geologist. The wells were installed and decommissioned as follows:

3.2.2.1 Overburden Monitoring Wells

Monitoring Well Decommissioning

Six (6) existing, overburden monitoring wells at the site were decommissioned due to the fact that they did not meet minimum construction standards, including several wells that were screened across the Tidal Marsh Deposits. These wells were installed by Geraghty & Miller in 1981, and included the following:

- **MW-1** – Located adjacent to the closed RCRA unit.
- **MW-1A** – Located adjacent to the closed RCRA unit.
- **MW-2** – Located adjacent to the closed RCRA unit.
- **MW-3** – Located adjacent to the closed RCRA unit.
- **MW-4** – Located adjacent to the closed RCRA unit.
- **MW-5** – Located adjacent to the closed RCRA unit.

These six wells were decommissioned in accordance with the requirements set forth in N.J.A.C 7:9D by a New Jersey-licensed well abandonment contractor. This included overdrilling of the PVC casings and grouting.

Existing Monitoring Wells

Four (4) existing, shallow monitoring wells were retained for use during the Phase I RI field investigation. These were previously installed by Eder in 1990, including the following:

- **MW-6S** – Located near the southeast corner, on the downgradient side of the closed RCRA unit
- **MW-7S** – Located on the east (downgradient) side of the closed RCRA unit
- **MW-8S** – Located near the northeast corner, on the downgradient side of the closed RCRA unit
- **MW-9S** – Located on the west (upgradient) side of the closed RCRA unit.

It should be noted that an "S" suffix has recently been added to these well designations to denote that they are shallow, overburden wells.

Phase I Monitoring Wells

The Phase I RI of groundwater consisted of the installation of eleven (11) Overburden monitoring wells. These wells were installed at the following locations:

- **MW-10S** – located near the brine sludge spill area

- **MW-11S** – located adjacent to Building No. 231, the "Purasiv Area"
- **MW-12S** – located near the 500K tank
- **MW-14S** – located near the drum storage pad
- **MW-15S** – to provide areal groundwater quality coverage in the central site area.
- **MW-16S** – to provide areal groundwater quality coverage in the northern most site area.
- **MW-17S** – to provide areal groundwater quality coverage in the western-most site area.
- **MW-18S** – to provide areal groundwater quality coverage north of the electrical switch yard.
- **MW-19S** – to provide areal groundwater quality coverage north of Building No. 220.
- **MW-20S** – to provide areal groundwater quality coverage south of the former Linde hydrogen plant.

It should be noted that an "S" suffix has recently been added to these well designations to denote that they are shallow, overburden wells.

Phase II Monitoring Wells

Five (5) additional monitoring wells were installed within the overburden to further define the extent of groundwater contamination within the fill. The locations of these monitoring wells are depicted on Figure 3-2 and were installed as follows:

- **MW-21S** – located southeast of Building 234 between borings RR-6 and RR-7 to address apparent free organic liquids observed in borings RR-6 and RR-7, and potential off-site migration.
- **MW-22S** - located southeast of Building 250 near borings PCA-4 and RR-4 to address apparent free organic liquids observed in borings PCA-4 and RR-4, and potential off-site migration.
- **MW-23S** - located west of Building 240 to characterize a groundwater level anomaly present at MW-5S.
- **MW-24S** – located at the former "Ditch Bridge Area" near boring WWT-1A to address elemental mercury observed in the soil.
- **MW-26S** – located in the area of the bullet tanks, north of Building 231 to address apparent free organic liquids observed in borings identified in BT-B1.

The monitoring wells were installed within the fill above the tidal marsh deposits, if present, or in the absence of the tidal marsh deposits, above the native soils, with the exception of MW-24S. MW-24S was installed a minimum of four (4) feet beyond the bottom of the former ditch bridge area which was backfilled with approximately 10 feet of clean, uncontaminated soil. The monitoring wells were installed and developed in accordance with Sections 3.3.1 and 3.3.2, respectively, the Field Operations Plan, Field Methods as presented in Appendix B.

3.2.2.2 Bedrock Monitoring Wells

Phase I

The approach for the Phase I RI of groundwater was to determine the nature and extent of contamination within overburden groundwater above the tidal marsh deposits. Accordingly, no bedrock monitoring wells were installed during the Phase I RI.

Phase II Wells

Based upon the findings from the Phase I, it was deemed necessary to delineate the vertical extent of groundwater contamination through the installation and testing of a number of bedrock monitoring wells. Accordingly, ten (10) bedrock monitoring wells were installed during the Phase II RI to characterize the groundwater within the bedrock water bearing zone. Each of the bedrock monitoring wells was installed at a depth interval approximately 10 to 20 feet below the top of the bedrock surface. The locations of

these monitoring wells are depicted on Figure 3-2. The locations of the bedrock monitoring wells were selected based on the following:

- **MW-6D** – to address elevated benzene, chlorobenzene, 1,2-dichlorobenzene, and 1,4-dichlorobenzene in the area adjacent to existing Overburden monitoring well (MW-6S).
- **MW 11D** – to address elevated mercury and VOCs in the area adjacent to Overburden monitoring well (MW-11S).
- **MW-14D** – to provide areal coverage within the bedrock water-bearing zone in areas in which elevated levels of mercury, arsenic, lead, aluminum and manganese were previously detected, adjacent Overburden monitoring well (MW-14S).
- **MW-16D** – to provide areal coverage within the bedrock water bearing zone in the area in which elevated levels of arsenic, chromium, benzene, and aluminum were previously detected adjacent Overburden monitoring well (MW-16S).
- **MW-17D** – to provide areal coverage within the bedrock water-bearing zone in the area in which elevated levels of metals and VOCs in the adjacent Overburden monitoring well (MW-17S).
- **MW-18D** – to provide areal coverage within the bedrock water bearing zone in the area in which elevated levels of metals and VOCs were previously observed in the adjacent Overburden monitoring well (MW-18S).
- **MW-20D** – to provide areal coverage within the bedrock water bearing zone in the area of the adjacent Overburden monitoring well (MW-20S) that previously contained elevated levels of arsenic, chlorobenzene, and manganese.
- **MW-21D** – to provide additional areal coverage within the bedrock water-bearing zone.
- **MW-23D** – to provide additional areal coverage within the bedrock water-bearing zone.
- **MW-25D** – to provide additional areal coverage within the bedrock water-bearing zone.
- **MW-27D** – to provide hydraulic (water level) data in the eastern-most accessible portion of the LCP site within the bedrock water-bearing zone. This well was installed in 2008 after the completion of other Phase II drilling activities for the specific purpose of evaluating the easterly extent of hydraulic capture as a result of bedrock groundwater pumping on the GAF site.

Each bedrock monitoring well was triple cased to minimize the risk of vertical migration of potential contaminants within the well annulus. The procedures for installing the triple-cased wells are described in Section 3.3.3 of the Field Operations Plan, Field Methods (Appendix B).

3.2.3 Rock Core Collection

Rock core samples were collected from borings that were drilled for the installation of bedrock monitoring wells. The rock core samples were used for visual examination of bedrock lithology.

Rock core samples were collected using an NX (3 inch outer diameter) core barrel in general accordance with ASTM Method D-2113. Each section of core was extruded from the core barrel and placed in a core box provided by the drilling contractor in accordance with ASTM Method D-5079. The core samples were photographed prior to detailed examination. A qualified geologist examined the core samples in the field. The geologist described the bedrock lithology, including, as appropriate, the percent core recovery, the prominent mineralogy, color and range, grain size and range, density, the nature of the boundary between recognized lithologies (e.g., gradual, abrupt, etc.), the presence of structural features such as fractures (including mineralization/in-filling material, if any), slickensides, breccia, gouge, shear zones, and discoloration by weathering or other phenomena. Rock quality was evaluated using the rock quality designation (RQD) method (ASTM D-6032). The procedures for rock core sampling are described in Section 3.3.3 of the Field Operations Plan, Field Methods (Appendix B).

3.2.4 Water Level Measurements

Water level measurements were obtained from each of the existing and newly installed monitoring wells and from the existing staff gauge on a minimum of four separate occasions to determine seasonal variations. Procedures for collecting the water level data were provided in Section 3.3.3 of the Field Operations Plan, Field Methods (Appendix B).

3.2.5 In-Situ Hydraulic Conductivity Tests

Variable head slug tests were performed to determine the in-place hydraulic conductivity of the unconsolidated and consolidated geologic material screened by the newly installed monitoring wells. These tests involve either rising or lowering the water level in the well and measuring the change in head with respect to time as the well is allowed to recover back to static conditions. Rising and/or falling head tests were conducted in all newly installed monitoring wells installed during each respective phase. The procedure for in-situ hydraulic conductivity testing is presented in Section No. 2.3 is provided in the Field Operations Plan, Field Methods (Appendix B).

3.3 Sample Collection

This section addresses sampling methodologies. Numerous samples were collected from each media investigated as discussed below. Collected samples were subjected to laboratory analysis. Please refer to Section 3.7 for a detailed discussion of analytes and associated methods for each sampled medium.

Comment [PJT45]: SC#7

Comment [PJT46]: SC#7

3.3.1 Soil Samples

3.3.1.1 Surficial Soil Investigation

Two hundred seventy-two (272) surficial soil samples were collected for laboratory analysis throughout the site as part of the Phase I and II RI field investigation. The locations of the surficial soil samples are shown on Figures 3-1 and 3-2. The surficial soil samples are listed along with the specific analytical methods employed on Table 3-1.

Most of the samples collected during the Phase I RI field investigation were collected at a depth of 0 to 0.5 feet below ground surface), as listed on Table 3-1. Conversely, most of the surficial samples collected during the Phase II RI were collected at a depth of 0 to 1.0 feet. A few other surficial soil samples were collected at other depth intervals up to 2.0 feet.

The surficial soil samples were collected by several methods. Many of the surficial soil samples were collected as a discrete sample with the use of direct-push (e.g., GeoProbe™) methods. Other surficial soil samples were collected as the upper-most sample interval from a deeper borehole, either by direct-push methods or using a split-barrel sampler in a hollow-stem auger borehole. Finally, a number of surficial soil samples were collected as a grab sample directly from the ground surface by manual methods. Descriptions of the surficial soil sample collection methods are presented in Appendix B (Field Operations Plan, Field Methods).

3.3.1.2 Subsurface Soil Investigation

One hundred fifty-three (153) subsurface soil samples were collected for laboratory analysis throughout the site as part of the Phase I and II RI field investigation. The subsurface soil samples are listed along with the specific analytical methods employed on Table 3-2. The locations of the subsurface soil samples are shown on Figures 3-1 and 3-2.

Samples collected during the Phase I RI field investigation were collected at a depths ranging from 2 to 14 feet below ground surface, as listed on Table 3-2. Conversely, the subsurface samples collected during the Phase II RI were collected at depths of 2 to 52 feet. Subsurface soil samples were collected to characterize the soil conditions in the deeper fill material, Tidal Marsh Deposits, and Glacial Till.

The subsurface soil samples were collected by two primary methods. Many of the subsurface soil samples were collected as a discrete sample with the use of direct-push (e.g., GeoProbe™) methods. Other subsurface soil samples at deep intervals were collected using a split-barrel sampler in a hollow-stem auger borehole. Descriptions of the subsurface soil sample collection methods are presented in Appendix B (Field Operations Plan, Field Methods).

3.3.1.3 Horizontal Borings

Soil samples were collected for laboratory analysis from various depths beneath Buildings 230 and 240 during the Phase I and Phase II RI field investigation. The sampling was performed by advancing horizontal borings beneath the floor slabs in accordance with methods provided in Field Operations Plan, Field Methods, (Appendix B). Horizontal borings were necessary due to the deteriorated condition of Buildings 230 and 240 which precluded a safe environment to perform conventional, vertical borings within the buildings.

Horizontal borings were drilled beneath Building Nos. 230 and 240 to characterize the soil conditions beneath the buildings. The borings started from the ground surface outside of the buildings, entering the ground at an angle and proceeding downward until the necessary depth was attained. The bore's path was then leveled, and the bore head steered horizontally to the desired completion point. Twelve (12) samples were collected from seven (7) horizontal borings during Phase I of the Remedial Investigation. Fifteen (15) samples were collected from (5) horizontal borings during Phase II.

Comment [PJT47]: SC#8

The locations of the horizontal borings soil samples are shown on Figures 3-1 and 3-2. Samples taken by horizontal boring methods are listed in Tables 3-1 and 3-2 along with the specific analytical methods.

3.3.1.4 Low Marsh Soils

Twenty-four (24) additional surficial soil samples were collected for laboratory analysis from the "low marsh" soils within and/or immediately adjacent to the narrow band of tidal wetland along South Branch Creek. These low marsh soil samples were collected as part of the Phase II RI field investigation. The locations of the low marsh soil samples are shown on Figure 3-2 and are listed along with the specific analytical methods employed on Table 3-3.

Low marsh soil samples were collected at a depth of 0 to 0.5 feet below ground surface as listed on Table 3-3. The low marsh soil samples were collected as grab samples directly from the ground surface by manual methods. Descriptions of the surficial soil sample collection methods are presented in Section 2.2 of Appendix B (Field Operations Plan, Field Methods).

3.3.2 Soil Vapor Samples

Fourteen (14) soil vapor and 2 ambient air samples were collected throughout the site as part of the Phase II RI field investigation. The soil vapor samples along with the specific analytical methods employed are listed on Table 3-4. The locations of the soil vapor samples are shown on Figure 3-2.

Soil vapor samples collected during the Phase II RI field investigation were collected from semi-permanent soil vapor probes screened in the thin vadose at a depth of between 0 and 4 feet below ground surface.

The vapor samples were collected by two methods. Samples for organic vapors were collected using a 1-liter SUMMA Canister set to collect a sample over a 1 hour time period. Samples collected for mercury vapor were collected using gold coated bead traps with a Teflon particulate filter. Descriptions of the vapor sample collection methods are presented in Appendix B (Field Operations Plan, Field Methods).

3.3.3 Groundwater Samples

Full rounds of groundwater quality samples were collected from each of the available monitoring wells during each of the Phase I and Phase II RI field investigations. These included collection of samples from each of the 15 shallow wells that were in place during Phase I and samples from the 31 overburden and bedrock wells as part of the Phase II RI field investigation. The groundwater samples along with the specific analytical methods employed are listed on Table 3-5. The locations of the groundwater monitoring wells are shown on Figures 3-1 and 3-2.

Samples collected during the Phase I RI field investigation were collected at the approximate midpoint of the well screen interval. Groundwater samples were collected using a low-flow purge and sample technique, utilizing bladder pumps. Additionally, the Phase II groundwater samples employed the "ultra-clean" sample collection and handling methods for the collection of mercury samples from groundwater per USEPA Method 1669 "Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels" (USEPA, 1996). Metals samples were collected as filtered and non-filtered samples.

Groundwater samples were collected for both total and dissolved constituents as described in Table 3-5. The filtered samples were field filtered using a 0.45 µm in-line filter on the pump discharge. Descriptions of the groundwater sample collection methods are presented in Appendix B (Field Operations Plan, Field Methods).

3.3.4 Surface Water Samples

Twenty-five (25) surface water samples were collected for laboratory analysis from South Branch Creek as part of the Phase I and II RI field investigations. The surface water samples were collected along transects evenly spaced out along the length of South Branch Creek and into the Arthur Kill at the locations shown on Figures 3-1 and 3-2. Four (4) surface water samples were also collected as part of the Off-Site Ditch Investigation. The locations of samples collected during the Off-Site Ditch investigation are shown on Figure 3-3. The surface water samples along with the specific analytical methods employed are listed on Table 3-6.

Comment [PJT48]: Ditch Report.

Samples collected during the Phase I RI field investigation were collected at mid depth in the water column as listed on Table 3-6. The samples collected during the Phase II RI were collected in the top two inches of the water column.

The surface water samples were collected as direct grabs for unfiltered samples. Samples collected for dissolved constituents were sampled from the mid point in the water column and field filtered using a peristaltic pump and a 0.45 µm in-line filter on the pump discharge. Samples for dissolved constituents during the Off-Site Ditch investigation were collected as direct grabs and filtered by the laboratory. Descriptions of the surface water sample collection methods are presented in Appendix B (Field Operations Plan, Field Methods).

Comment [PJT49]: Ditch Report

3.3.5 Sediment Samples

Fifty-eight (58) sediment samples were collected throughout South Branch Creek and the concrete drainage channel as part of the Phase I and II RI field investigation. The sediment samples were collected along transects evenly spaced along the length of South Branch Creek and into the Arthur Kill at the locations shown on Figures 3-1 and 3-2. Twelve (12) sediment samples were also collected as part of the Off-Site Ditch investigation. Samples collected during the Off-Site Ditch investigation were

Comment [PJT50]: Ditch Report

collected along three transects in both the northern and southern ditches. The sediment samples along with the specific analytical methods employed are listed on Table 3-7.

Samples were collected during the Phase I and II RI field investigations at a depth interval of 0 to 0.5 feet at each location. Additional deeper sediment samples were collected during Phase II at numerous other locations at 0.5 foot intervals to a maximum depth of 2.5 feet as listed on Table 3-7. Vertical depth samples obtained during the Off-Site Ditch investigation were collected in 2-foot vertical intervals.

Comment [PJT51]: Ditch Report

The sediment samples were collected by two primary methods. Many of the surficial sediment samples were collected as a grab sample with the use of "Petite Ponar" dredge or dedicated sampling spoon. Sediment samples collected from locations at depths greater than 0.5 feet were collected using a sediment coring device with polycarbonate tubing. Sediment samples targeted for AVS/SEM analysis were collected with minimum disturbance and exposure to air. Descriptions of the surficial soil sample collection methods are presented in Appendix B (Field Operations Plan, Field Methods).

Comment [PJT52]: Ditch Report

3.3.6 Biota Samples

Eighteen (18) biota samples were collected from South Branch Creek as part of the Phase II RI field investigation. The Biota samples comprise of 6 Mummichog (*Fundulus heteroclitus*) tissue samples and 12 Fiddler Crab (*Uca spp*) tissue samples. The sampling locations were co-located with the sediment chemistry sample locations. The biota samples are listed along with the specific analytical methods employed on Table 3-8.

Biota samples were collected along transects evenly spaced along the length of South Branch Creek as shown on Figure 3-2, Mummichog samples were collected at the midpoint of the channel, while Fiddler Crab samples were collected near the shoreline on both sides of the channel.

Mummichog samples were collected primarily using minnow traps. However samples were also collected with a seine net. Fish samples were rinsed, weighed, and measured prior to being shipped to the laboratory. Fiddler crab samples were collected by hand capture, and similarly weighed and measured before being sent to the laboratory. Descriptions of the biota sample collection methods are presented in Appendix B (Field Operations Plan, Field Methods).

3.4 RI Work Plan Deviations

A number of deviations from the approved work plan documents were necessitated during the course of the Phase I and Phase II RI and Off-Site Ditch field investigations. These were required due to various field conditions and were made in consultation and approval with representatives from USEPA and/or their oversight contractor.

Comment [PJT53]: Ditch Report

3.4.1 Phase I Remedial Investigation

The RI Work Plan deviations that were made during the Phase I RI field investigation are described in the subsections that follow.

3.4.1.1 Between Building Nos. 220 and 230

Two proposed soil borings, BB-1 and BB-2, were not advanced in the area between Building Nos. 220 and 230. Building Nos. 220 and 230 are physically connected and therefore, no space was available for sample collection between these two buildings.

3.4.1.2 Sampling Beneath Building Nos. 230 and 240

The sampling locations identified beneath Building Nos. 230 and 240 in FOP Addendum No. 3 were modified due to subsurface obstructions and soil conditions. The final locations are shown on Figures 3-1 and the modifications included:

- The collection of only one sample at horizontal boring locations HB-1 and HB-2 rather than four as was specified. Physical access beneath the building prevented the collection of a shallow sample and debris within the sump prevented the lateral advancement of the boring.
- The relocation of horizontal boring HB-3 to the north by approximately 13.5 feet. This was required due to the presence of an extensive network of subsurface foundation piles along the common wall between Building Nos. 230 and 240.
- The collection of only one sample at horizontal boring location HB-4 rather than four as was specified. Additional samples could not be collected due to building obstructions and the presence of shallow tidal marsh deposits.
- The collection of only one sample at horizontal boring location HB-5 rather than four as was specified. The lateral advancement of the boring past the sump was not possible due to lack of soil competency. This was manifested by very soft fill soil conditions which made it impossible to maintain the boring on a level, horizontal track.
- The collection of no samples from horizontal boring HB-6 due to subsurface obstructions. The subsurface obstructions included the foundation piles beneath the "shed", the foundation piles beneath the foundation and floor, and the active New Jersey-American Water Co. (formerly Elizabethtown Water Co.) water main located partially below ground surface in this area.
- The collection of three additional samples at a new horizontal boring location, HB-8. HB-8 was advanced from east to west under Building 240 near HB-5. This boring was added to provide additional lateral coverage beneath Building No. 240.
- The collection of one additional sample at a new horizontal boring location, HB-9. HB-9 was advanced from east to west beneath Building 240 near the South Extension. The addition of this boring provided sample coverage near the south extension of Building No. 240. Sampling beneath the south extension was not possible due to numerous subsurface building obstructions.

3.4.1.3 Along Railroad Track

Two proposed soil borings, RR-13 and RR-14, were not advanced, as they were located outside of the site property boundaries. At the time of the FOP preparation, an adequate property line survey had not yet been performed on the site. Therefore it was unknown at that time that these borings would be located off of the property.

3.4.1.4 Areas of Suspected Past Releases

Additional soil samples were collected in the two suspected past release areas north of Building No. 221 to provide better sample coverage within these areas. These included:

- One additional sample from the area identified in a 1963 aerial photograph as a light-toned surface stain, SPR-2.
- Two additional samples from the area of puddles, SPR-4, identified in the 1974 aerial photograph.

3.4.1.5 Leaking Overhead Pipe Area

Two LP borings, LP-6 and LP-12, were moved at the request of the USEPA to the area south of the closed sludge lagoon from the area between the railroad tracks and the closed sludge lagoon. These borings were moved to provide sample coverage for the area south of the closed sludge lagoon.

3.4.1.6 Former Drum Storage Area

The drum storage pad (DSP) soil borings were to be advanced at each side of the drum storage pad. The boring locations were modified due to the presence of an active 24-inch Elizabethtown Water Co. water main and the site property boundaries. The locations and identification of each of the soil, groundwater, surface water, and sediment samples are depicted on Drawing No. 21405-001.

3.4.2 Phase II Remedial Investigation

The FOP deviations that were made during the Phase II RI field investigation are described in the subsections that follow. The locations of the Phase II RI samples are depicted on Figure 3-2.

3.4.2.1 Deep Soils

The installation of bedrock monitoring well MW-25D deviated from the method described in "FOP No. 4 (Bedrock Monitoring Wells, Soil Vapor Testing, Groundwater Sampling)", due to encountered subsurface conditions. After the completion of the initial borehole through the anthropogenic fill material, the 10-inch steel casing was installed into the top of the tidal marsh deposits as described in Section 3.3.1.1 of FOP No. 4. Once the grout had set, drilling and sampling continued into the tidal marsh deposits to a point where elemental mercury was visibly observed at the 12 to14-foot interval. The boring was terminated and the borehole abandoned as described in the RIWP. In accordance with e-mail and verbal communications with Mr. Jon Gorin of USEPA, a new boring was drilled and the initial 10-inch casing was installed, deeper than previously prescribed, to the base of the tidal marsh deposits to prevent vertical migration of the observed metallic mercury.

3.4.2.2 Horizontal Borings beneath Buildings 230 and 240

Several of the sampling locations beneath Building Nos. 230 and 240 were required to be slightly modified due to subsurface obstructions and soil conditions. These modifications included:

- The sampling locations for Horizontal Boring 102 (HB-102A, HB-102B, etc.) were moved from the proposed line across the southern portion of Building 230 to the northern portion of the building, but still south of the HB-101 location. This relocation was made with approval of USEPA contractor's and Mr. Jon Gorin of USEPA due to difficult drilling conditions in the original locations that prevented the horizontal sampling device from operating properly. The purpose of the HB-102 boring was to collect samples beneath the collection trench in Building 230. By moving the boring location to the north, the samples were collected beneath the northern section of the collection trench rather than the southern section, satisfying the original goal of collecting the horizontal samples.
- Horizontal boring HB-102 was terminated after the third sample (HB-102C) was collected. Thus, no D or E sample was collected as intended in the work plan. This deviation was made in consultation and approval of USEPA due to the continued difficult drilling conditions and because the intent of the samples were to collect samples "between the trench and the common wall between Buildings 230 and 240." From the drawings used to locate the horizontal borings (see Addendum No. 3, Field Operations Plan for the LCP Chemicals, Inc. Superfund Site, Sampling Beneath Buildings 230 and 240, Appendix A), the collection trench ended approximately 150 ft. from the western wall meaning the three samples collected accomplished the goal of evaluating areas beneath the collection trench in Building 230.

3.4.2.3 Groundwater Quality Characterization

Groundwater sampling in each of the existing and newly installed monitoring wells was conducted between January and March of 2007. Sampling procedures followed Addendum No. 4, Field Operations Plan, LCP Chemicals, Inc. Superfund Site (Bedrock Monitoring Wells, Soil Vapor Testing, Groundwater Sampling (April 2006, Revised October 2006). It was determined that the majority of the monitoring wells yielded water at a low rate, which is not surprising given the relatively low hydraulic conductivity of

the screened material and the depth of the "S" wells. Accordingly, it was found that the water levels would not stabilize as per the RIWP in several of the wells during the low-flow purging. In one extreme instance (well MW-26S); it was not possible to perform all of the chemical analyses specified in the work plan due to insufficient sample volume.

Additional groundwater quality samples were collected from select overburden and bedrock monitoring wells in September 2007 which were subjected to analysis for total chloride and total dissolved solids (TDS). These samples were collected in accordance with the *Field Sampling Procedures Manual*, (NJDEP, 2005).

3.4.2.4 Soil Vapor Characterization

Soil Vapor probes were installed in December of 2006 but were not sampled until June of 2007 due to the condition of the vadose zone. Specifically, high groundwater conditions and/or frozen soil conditions prevented the development of an adequate vadose zone for sampling until late spring. Once the vadose zone was adequately developed, however, an inspection revealed that two (2) soil vapor probes had been destroyed and one was no longer safe to be sampled, as follows:

- SV-6 was installed to the west of a large tank pad south of the MW-11 cluster and was damaged beyond repair and was not sampled. It is likely that this probe was hit by a vehicle or construction equipment and insufficient time was available to replace it.
- SV-7 was installed south of Building No. 240 unit and adjacent to MW-13. The deteriorated structural condition of the building since the initial installation has rendered access to areas surrounding the closed Building No. 240, and by default SV-7, to be unsafe due to the potential for falling debris to injure field personnel. Furthermore, the area around SV-7 continued to be flooded such that a vadose zone never developed from which to collect a soil vapor sample.
- SV-11, installed on the northern portion of the Site northeast of Building 220, was damaged beyond repair and not sampled. It is likely that this probe was hit by a vehicle or construction equipment and insufficient time was available to replace it.

The remaining soil vapor probes were sampled in accordance with the RIWP

3.4.2.5 South Branch Creek Sediment and Surface Water Samples

- Two sediment samples collected from South Branch Creek (SED-E-1-0.0-0.5 and SED-E-3-0.0-0.5) were not analyzed for Total Organic Carbon, due to insufficient volume recovery.
- Surface water samples were not analyzed for Particulate Organic Carbon (POC). The initial analyses showed that there was very little POC. To allow a complete analysis, a vast volume of water per sample would have been required. Therefore it was not technically feasible to analyze for POC.
- Surface water samples were inadvertently not analyzed for the Oxidation Reduction Potential (ORP) in the field.
- In addition to the parameters that were required in the RIWP, surface water samples were analyzed for conductivity, turbidity and temperature.

3.4.2.6 Sediment Toxicity Testing

According to "Supplemental Work Plan: Sediment Toxicity Testing (South Branch Creek), Phase II Remedial Investigation LCP Chemicals, Inc. Superfund Site," (Brown and Caldwell, September 2006, Revised October 2006) sediment toxicity testing was to be performed on three sediment samples from South Branch Creek. Three sediment samples were collected, but two of the three samples were found to emit sufficient elevated mercury vapors upon agitation at the laboratory, and could not be tested safely. After discussion with and approval by EPA, only one sample from South Branch was tested for sediment toxicity.

3.4.3 Off-Site Ditch Investigation

Comment [PJT54]: Ditch Report

Modification of the physical parameter measurements was necessary due to the field conditions that were encountered during the investigation, as follows:

- The upstream 600-ft segment of the Northern Off-Site Ditch, between markers ND-1 and ND-12, was not a singular drainage channel as was anticipated during planning, but rather a grassy marsh without a single defined channel. Given this condition, meaningful flow velocity measurements could not be taken for the upstream reaches of the northern ditch.
- Due to a steep bank on the Southern Off-Site Ditch, sediment thickness measurements could not safely be taken at each 50 foot marker along the ditch channels. In such cases, an average of the thickness of the upstream and downstream marker was used as an approximation. In these areas, ditch channel width estimates were taken off of aerial photos utilizing Geographic Information Systems (GIS) as a substitute when accessibility of the channel was impaired.

3.5 Additional Fieldwork

Additional fieldwork and field data collection were performed that was not described in the RIWP. This work is described in the following sections.

3.5.1 Shallow Soils

Two additional shallow soil samples were collected using direct-push technology at the request of ISP-ESI. These borings were LHP-127 and LHP-128, each of which is located north of the Praxair Hydrogen Plant along the railroad tracks (see Figure 3-2). Soil samples were collected and analyzed for the same suite of analyses as the rest of the shallow soils including TCL/TAL, CR $^{6+}$, TOC, and pH.

3.5.2 Hydrogeologic Data

No provision was made in the RIWP (URS, 2001) for evaluating the tidal influence on any of the newly installed bedrock monitoring wells during the Phase II RI. Accordingly, the following additional data were obtained:

- Collection of grab groundwater samples of the water column within the bedrock monitoring well-casing to be analyzed for specific gravity for potential density correction of measured water levels due to the presence of saline water in the bedrock water-bearing zone.
- Installation of pressure-transducers with data-logging capabilities (In-Situ© Level Trolls) to record water level changes within the wells. The results were compared to data collected from data-loggers installed in South Branch Creek and the Arthur Kill.

3.5.3 Surface Water Data

Additional surface water data were collected during the Phase II RI at a downstream station in South Branch Creek to provide information on ~~the flux of~~ mercury ~~to the Arthur Kill and an estimate of freshwater (groundwater) inflow to South Branch Creek~~ in surface water. Additionally, samples from this location were collected to provide a comparison of the salinity in the tidal waters within South Branch Creek and groundwater discharging to South Branch Creek. These additional data included the collection of filtered and non-filtered surface water samples at two-hour intervals throughout an entire tidal cycle on February 5 and 6, 2007. The samples were collected using a peristaltic pump at the approximate mid-depth of the water column carefully to not disturb the bottom sediment. Field filtration was accomplished using a 0.45µm in-line filter on the pump discharge. Laboratory analyses included total mercury on both the filtered and non-filtered samples and total suspended solids (TSS) on the non-filtered samples. Field measurements were also made using a multi-parameter meter (Horiba U-10) with

Comment [PJT55]: SC#10

a long lead directly into water at the approximate mid point of the water column and included pH, temperature, salinity, conductivity, DO, and turbidity.

3.5.4 Soil and Sediment Data

Additional surficial soil and sediment samples were collected in May 2008 to further characterize mercury contamination on the site and in South Branch Creek.

Eight (8) additional surficial soil samples were collected from areas that were previously characterized as having low, moderate, and elevated concentrations of total mercury in soil. These samples are intended to bracket the range of concentrations of mercury on the site and assist the human health risk assessment. These samples were collected by manual grabs and analyzed by Frontier Geosciences, Inc of Seattle, WA. Samples were analyzed for total and elemental mercury.

Four (4) additional surficial soil samples were collected from areas previously known to exhibit visible, metallic mercury in surficial soil. These samples were intended to evaluate the leachability of elemental mercury from soils containing visible elemental mercury for potential waste characterization purposes. Samples were collected as manual grabs and analyzed by Accutest Laboratories of Dayton New Jersey. Samples were analyzed for total mercury and TCLP mercury.

Seven (7) additional sediment samples were collected from three (3) locations. These samples are intended to evaluate the mercury speciation and relative mercury mobility within South Branch Creek sediments. A single 0 to 0.5 ft. depth surficial grab was collected at two (2) locations and a sediment core to a complete depth of 2.5 feet was collected at a third location from which individual aliquots were taken in 0.5-foot intervals. The surficial grab samples were collected using Petite Ponar dredges, while the core was taken using a sediment coring device with polycarbonate tubing. Samples were analyzed by Frontier Geosciences, Inc of Seattle, WA for total mercury and mercury sequential extraction (inorganic speciation).

3.6 Field QA/QC Samples

Quality control procedures were utilized to evaluate and document the bias associated with sample container preparation, sample collection, and sample transport activities. This involved the collection and analysis of various field QA/QC samples including trip blanks, field blanks and field duplicate samples. These samples were utilized in addition to the various method-required, laboratory QA/QC samples including MS/MSD samples, lab duplicates, etc.

3.6.1 Trip Blanks

Trip blanks were prepared only when aqueous sampling was performed, and only when the sampling involved VOC analysis. A trip blank consisted of an analyte-free water sample prepared by the laboratory that accompanied the sample container shipment from the laboratory to the field and back. Trip blanks were subject only to VOC analysis. Trip blanks were collected at a rate of one per sample shipment or one per two day sampling event, whichever is greater.

3.6.2 Field Blanks

Field blanks consisting of analyte-free water poured over representative pre-cleaned sampling equipment were utilized, where applicable. For aqueous sampling, field blank samples were analyzed for the same parameters as the aqueous samples. For non-aqueous sampling, field blanks were analyzed only for VOCs whenever VOCs were part of the non-aqueous sample analytical program. Field blanks were collected at a rate of one for each day of sampling or one per 20 samples, which was greater.

3.6.3 Field Duplicate Samples

Field duplicate samples were collected as a measure of laboratory repeatability. The duplicate samples were collected at a rate of one (1) sample per twenty (20) samples for each parameter that is to be analyzed. Field duplicate samples were collected in addition to MS/MSD laboratory QA/QC samples that also involved the collection of field duplicates.

3.7 Laboratory Methodology

3.7.1 Soil, Groundwater, Surface Water, and Sediment Analysis

Samples from most soil, groundwater, surface water, and sediment were submitted for laboratory analysis by Accutest Laboratory, Inc. in Dayton, New Jersey. Accutest was involved with the preparation of the QAPP (URS, 2001). The analytical methods, containers, and holding times are listed on Table 3-9. The samples were tested for the following constituents:

- Target Compound List (TCL) Volatile Organic Compounds (VOCs), in accordance with USEPA SW-846 Method 8260B
- VOC tentatively identified compounds (TICs), in accordance with USEPA SW-846 Method 8260B
- TCL Semi-volatile Organic Compounds (SVOCs), in accordance with USEPA SW-846 Method 8270C
- SVOC TICs, in accordance with USEPA SW-846 Method 8270C
- TCL Pesticides and Herbicides, in accordance with USEPA SW-846 Method 8081A
- TCL Polychlorinated Biphenyls (PCBs), in accordance with USEPA SW-846 Method 8082
- TAL Metals, in accordance with USEPA SW-846 Methods 6010B, 7470A (aqueous samples only), and 7471A (non-aqueous samples only)
- Cyanide, in accordance with USEPA SW-846 Method 9012 and USEPA Method 335.3
- Polychlorinated naphthalenes were reported as VOC TICs and SVOC TICs
- Total Organic Carbon (sediment and surface water samples only)
- Hardness, Total Dissolved Oxygen and Total Suspended Solids, pH, Conductivity. Turbidity, Temperature, and Salinity (surface water samples only)
- TDS and chloride (selected groundwater samples only)
- Mechanical grain size (sediment samples only)

A select group of samples were subcontracted by Accutest Laboratories, as follows:

- SGS in Wilmington, North Carolina (previously known as Paradigm Analytical Labs) analyzed selected samples for Polychlorinated dibenzodioxins (PCDDs) and Polychlorinated dibenzofurans (PCDFs), in accordance with Method 1613.
- Battelle/Marine Sciences Laboratory in Sequim, Washington analyzed selected samples for methyl mercury in both soil and groundwater via laboratory standard operating procedure (SOP). Battelle also performed a sequential extraction on soil samples for mercury following the method described in Bloom, et. al. (2003).
- Columbia Analytical Services (CAS) in Kelso, Washington analyzed selected samples for methyl mercury in both aqueous and soils samples via laboratory standard operating procedures (SOP).

3.7.2 Soil Vapor and Ambient Air Analysis

- Soil vapor and ambient air samples were analyzed for Volatile Organic Compounds using Method TO-15 by Accutest Laboratories in Dayton, New Jersey.
- A select group of soil vapor samples were analyzed for mercury vapor in air via Method IO-5 by Frontier Geosciences in Seattle, Washington.

3.7.3 Biota Analysis

Chemicals of Potential Ecological Concern (COPECs) were identified in the Interim Ecological Risk Assessment Problem Formulation (Brown and Caldwell, October 2006). COPECs for the semi-aquatic portion of the site are PCBs, arsenic (total and arsenobetaine), barium, chromium, copper, iron, lead, manganese, mercury (total and methylmercury), vanadium, and zinc.[4]

- Columbia Analytical Services (CAS) in Kelso, Washington analyzed biota tissue samples for PCBs by EPA Method 1668A, and arsenic, barium, chromium, copper, iron, lead, manganese, mercury, vanadium, zinc, and percentage lipid body weight by laboratory standard operating procedures (SOPs).
- Arsenic speciation analysis in biota tissue samples was performed by West Coast Analytical in Santa Fe Springs, California, following the method described in Sans, et. al. (2005).

3.7.4 Sediment Toxicity

American Aquatic Testing Inc. in Allentown, Pennsylvania performed sediment toxicity testing on sediment samples following the method described by the USEPA Office of Research and Development (1994).

3.8 Other Field Activities

3.8.1 Site Topographic Survey

A site topographic survey map was provided by Keller & Kirkpatrick in a map dated March 14, 2001. The mapping was based on aerial photography by Atlantis Aerial Survey Co. Inc. on December 5, 2000. A boundary line survey was not provided as part of this mapping.

3.8.2 Wetland Delineation

Wetland delineation was performed by EcolSciences, Inc., (EcolSciences) in 2006, and a wetland boundary map dated September 16, 2006, was submitted to NJDEP. The Letter of Interpretation (LOI) was issued by the NJDEP on February 16, 2007 (Appendix E).

3.8.3 Habitat Assessment

The Chazen Companies (TCC) completed an Ecological Assessment (EA) as part of the Phase II RI in August 2007. The EA methodology consisted of information gathered from federal, state, and local agencies, supplemented by Site visits designed to identify and characterize the LCP site's flora and fauna. Additionally, the Site was studied for the presence of endangered, threatened, and/or rare (ETR) species and their habitats.

During the field investigations, plant and animal species were inventoried to characterize existing populations, habitats, and communities. The potential for rare plants and animals, as well as general observations regarding overall plant community composition and structure, wetlands and watercourses,

[4] PCDDs/PCDFs were potential COPECs pending results of the sediment analyses. These constituents were never analyzed in tissue.

the degree of site disturbance, and other site characteristics were noted and recorded during the site inspection. The LCP site was transected in its entirety excluding entering hazard zones (i.e., on-site buildings) to ensure that each vegetative community type was surveyed. An EA report was prepared by TCC and is attached in Appendix F.

In addition to investigating the LCP site, other areas within a half mile perimeter from the LPC site were investigated to document vegetation and the presence of wildlife species which live in the area. Moreover, a literature review was conducted to provide supporting documentation for use in the EA. Information gathered included topographic maps, soil and geology maps, aerial photographs, pertinent plant and animal species information (i.e., known species in the area, characteristics required for identification, etc.), historical information, and information on the Pralls Island heron rookery.

3.8.4 Location Survey

The horizontal and vertical positions of site features, sample locations, and monitoring wells were provided by Keller and Kirkpatrick, a New Jersey licensed surveyor. Locations were referenced to New Jersey State Plane (North American Datum 1983) coordinates in feet.

3.8.5 Subsurface Utility Clearance

The drilling or excavation contractors were responsible for contacting the New Jersey "One-Call" System prior to performing any subsurface drilling or excavation work. The utility company mark-outs provided by the "One-Call" service were required to address underground public utility lines (e.g., gas, water, electric, communications, etc.) regardless of whether or not they are on private property. Previous site documents and utility maps (where available) were also reviewed to provide clearance for the sampling locations. Further supplemental utility clearance was also performed in the vicinity of each drilling location in addition to the "One-Call" notifications, as described above. This supplemental clearance was required given the uncertainty of the previous mark-outs provided under the "One-Call" system and/or to locate other on-site (non-public) utilities. The supplemental utility clearance was performed with the use of an inductive pipe locator. Alternatively, a radio-frequency pipe locator was used, as applicable.

3.8.6 Tank Assessment

The storage tanks remaining at the site were evaluated during the Phase I RI to determine their potential for releasing constituents to the environment. This assessment consisted of a survey and inventory of the existing tanks and a visual evaluation of their apparent integrity. If past or future releases from a given tank appeared likely, then a sample of the product inside the tank, if any, was to be collected and submitted to the laboratory for analysis. The tank inventory is presented in Table 2-8.

No additional samples were submitted to the laboratory for analysis as a result of the tank assessment during the Phase I. The tanks that were suspected to have had past releases or had the potential for future releases were found to contain no product within the tanks for sampling, with the exception of the "bullet tanks" in Building 240. Although the bullet tanks were suspected to have had a past release and contained product, they were not sampled because the tank contents were not accessible for sampling due to the absence of a sampling port or other viable alternative means.

Based on the results of the Phase I tank assessment, the contents of a 150,000 gallon former brine tank was sampled during the Phase II RI. The sample was submitted to the lab to be analyzed for pH, total dissolved solids, and metals.

Section 4

Data Management

Sample and laboratory analysis data obtained as part of the Phase I and II field investigations were managed in accordance to the procedures described in the following sections.

4.1 Sample Nomenclature

The groundwater, surface water, low marsh soils, sediment, biota and soil vapor samples collected at the site were assigned the following, standard designations:

- "MW " prefix for groundwater monitoring well samples
- "SW " prefix for surface water samples
- "SED " prefix for sediment samples
- "SV " prefix for soil vapor samples
- "FC " prefix for crab samples
- "MC " prefix for fish samples
- "LM " prefix for low marsh soil samples

Soil samples were assigned a designation based on the name of the area of concern that they are associated with or the borehole from which they were collected (Table 4-1).

4.2 Data Quality and Validation

Chemical laboratory analytical data obtained as a part of the RI field investigation were validated by Data Validation Services of North Creek, New York. The validation was performed in accordance with the following documents:

- "National Functional Guidelines for Organic Data Review", (USEPA, October 1999).
- "USEPA Region II Validation Standard Operating Procedures (2004)."
- "Quality Assurance Project Plan, Field Operations Plan, Part II, Draft Sampling and Analysis Plan" (URS, February 12, 2001),

The data validation was performed separately for each laboratory Sample Delivery Group (SDG). The reports include a validation summary and tables listing the laboratory and client sample ID's (see Appendix D for copies of Data Usability Reports). Validation qualifiers were added by the validator and transmitted electronically to BC for direct entry into the database. The notations used for data validation include the following validation qualifiers:

- **U** - the analyte was analyzed for, but was not detected above the reported sample quantitation limit.
- **J** - the analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
- **N** - the analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification."
- **NJ** - the analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.

- **UJ** - the analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
- **R** - the sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

The aforementioned validation qualifiers have been added to the database, presented on CD ROM in Appendix E. A list of rejected data is presented in Table 4-2.

4.3 Environmental Database

A relational database has been developed to provide data entry, secure storage, access, and analysis capabilities of the field and analytical laboratory data obtained during the Phase I and II RI field investigation. The database resides on an SQL-Server with a Microsoft Access™ user interface. Accordingly, queries from the database provide data output used in the preparation of data tables and graphs. In addition, the database is fully integrated with the geographic information system, described below.

Laboratory data were provided as electronic data deliverables (EDDs) in a specific format that was designated by BC. The EDDs were imported directly into the database and were checked against conventional laboratory reports. Full laboratory data deliverable packages were also provided in electronic form in indexed PDF files and as hard copy. The PDF files are provided in Appendix H. The hard copy laboratory deliverable reports were previously provided to USEPA.

A CD ROM is included with this submittal (Appendix K) which includes the analytical database, in Microsoft Access™ format of the data obtained from the Phase I and II Remedial Investigation (RI) of the LCP Chemicals, Inc. Superfund Site. Table 4-3 describes the database structure including the various tables and database fields and the relationships between the tables.

4.4 Geographical Information System (GIS)

A geographic information system (GIS) database was developed to manage and report analytical and other site data. The graphical GIS output is managed using ESRI ArcGIS® software that is dynamically linked to the database. The GIS is utilized to aid in the interpretation of the site information because of its utility to evaluate and display large amounts of spatial data with a high level of efficiency and accuracy.

Section 5

Physical Characteristics

5.1 Site-Specific Geologic Conditions

The characteristics and extent of the geologic materials encountered within the study area are described in this section. This draws from the discussion of regional geologic conditions as presented in Section 2.6. The site specific geologic conditions of the study area are based upon interpretation of data generated during this and previous field investigations at this site and at the adjacent GAF site. Four lithologic units are observed beneath the site between ground surface and depths of approximately 60 feet as shown in a generic stratigraphic column (Figure 5-1).

The surficial (overburden) materials and bedrock encountered beneath the site include:

- A heterogeneous mixture of anthropogenic fill.
- A tidal marsh deposit layer consisting of a peat subunit and an organic silt and clay subunit.
- A glacial till unit.
- Bedrock of the Passaic formation, consisting of a residual soil subunit and a competent bedrock (mudstone) subunit.

A glacial fluvial sand unit above the glacial till is intermittently present in the region, including at the adjacent ISP ESI Linden site and at the former American Cyanamid Warners Plant. Glacial-fluvial sand, however, has not been encountered in the numerous borings beneath the LCP site and is likely not present.

The upper surface of the tidal marsh deposits (base of fill), glacial till, and the bedrock, are depicted on Figures 5-2, 5-3, and 5-4, respectively. These surfaces have been contoured based on borehole data obtained from the LCP site and the adjacent GAF facility site to the north.

The aforementioned geologic units are also shown on two (2) representative geologic cross-sections, Figure 5-6. The orientation of the cross-sections is provided on Figure 5-5. The cross-sections are constructed with a vertical exaggeration of ten times (10X). The cross-sections are prepared through the integration of the four surfaces representing the ground surface, and the top of the stratigraphic units presented in Figures 5-2, 5-3, and 5-4. The cross-sections are carried through wells that provide a geologic representation of the major stratigraphic units, including fill, tidal marsh deposits, glacial till, and bedrock along alignments that generally trend east to west and north to south, respectively.

Detailed descriptions of the materials as they were encountered in the individual boreholes can be obtained from the boring logs contained in Appendix A. Generalized descriptions of the units are provided below.

5.1.1 Surficial Geology

5.1.1.1 Anthropogenic Fill

The entire site is covered with a layer of anthropogenic fill that continuously overlies the natural tidal marsh soils. The fill ranges in thickness from ~~0.7~~ 1 to 16~~17~~ feet, with an average thickness of approximately 9 feet. The elevation of the anthropogenic fill is typically about seven to nine feet NGVD (North American Geodetic Vertical Datum of 1929) but ranges from less than two feet NGVD along South Branch Creek to above 24 feet NGVD on the closed RCRA unit. The anthropogenic fill consists of an

Comment [PJT56]: SC#11

irregular mixture that is primarily of soil but is characterized by the frequent presence of anthropogenic materials, including ash, wood fragments, bricks, and glass.

5.1.1.2 Tidal Marsh Deposits

Marine tidal marsh deposits underlie the anthropogenic fill unit throughout the site. The approximate thickness of the unit has been observed to range from ~~5 to 10.5~~ 2 to 11.5 feet. The unit has been subdivided into two subunits, including a peat layer and an organic silt and clay layer. Each of the subunits can generally be described, as follows:

Comment [PJT57]: SC#12

- **Peat** - Peat is brown to black, loose, fibrous, very soft, and water-saturated. It is formed from the decomposition of plant remains. Hydrogen sulfide, a natural by-product of decomposing organic matter, is commonly evident in this subunit. Minor amounts of fine-grained sand and black organic silt and clay are mixed with the peat. This layer grades vertically downward into the underlying organic silt and clay subunit and forms a transitional contact between the two subunits.
- **Organic Silt and Clay** - the organic silt and clay subunit is typically described according to the Burmister Classification System (Burmister) as: "Gray to black SILT to CLAY, none to some fine Sand". These sediments were deposited when fine-grained sediments flocculated by brackish tidal waters were subsequently deposited (Anderson, 1968). In addition, it is possible that some of these sediments represent backswamp deposits, silts, and clays that were deposited in flood basins of rivers and streams during abnormally high water conditions.

The position of the top surface of the tidal marsh deposits is depicted on the "Top of Tidal Marsh Deposits Structural Contour Map" (Figure 5-2). This map was prepared by the Kriging method from over 100 available borehole data points. The top of the tidal marsh deposits is also depicted on the two (2) geologic cross-sections (Figure 5-6).

The top of the tidal marsh deposits ranges in elevation from 7.8 to -10 feet NGVD. The surface is highly irregular with no particular pattern and likely results from the differential compaction and heaving due to the placement of the overlying anthropogenic fill.

5.1.1.3 Glacial Till

Glacial till underlies the tidal marsh layer. Glacial till represents ground moraine deposits formed from the scouring and subsequent redeposition of the underlying Passaic formation by the glacial ice. This is evidenced by the similar red-brown color and very fine-grained particle size of the glacial till sediments. The glacial till can generally be described according to Burmister as: "Red-brown SILT & CLAY to CLAY & SILT, none to some fine-medium Gravel, none to little fine to fine-medium-coarse Sand." The gravel commonly includes fragments of diabase, which is a diagnostic feature distinguishing this unit from the underlying residual soils of the Passaic formation.

The glacial till is observed to range in thickness from ~~18.5 to 20.5~~ 17.5 to 30.5 feet. The position of the top of the glacial till is depicted on the "Top of Glacial Till Structural Contour Map" (Figure 5-3) and also on the two (2) geologic cross-sections (Drawing No. 135451-002). The glacial till surface generally slopes in an east northeasterly direction toward the Arthur Kill from an observed high of -3.0 feet in the southwest portion of the site to -20.5 feet near the Arthur Kill.

Comment [PJT58]: SC#12

5.1.2 Bedrock Lithology

The Passaic formation is denoted as the upper bedrock formation and underlies the glacial till unit. This formation has been divided into two subunits based upon the relative degree of decomposition, including the upper residual soil subunit and the lower competent bedrock subunit. Each of the subunits can generally be described, as follows:

- **Residual Soil** - the residual soil subunit, the uppermost portion of the Passaic formation, is the result of the in place decomposition of the underlying bedrock. Typically, these soils are a mixture of red brown clays, silts and resistant shale fragments and resemble the overlying glacial till sediments. The contact between both units is usually definite, but sometimes difficult to distinguish. Diagnostically, the absence of diabase rock fragments in the residual soils distinguishes it from the overlying till unit because the till represents a transported material from the north, whereas the residual soil was formed in place.
- **Competent Bedrock** - the transition between the residual soil and the underlying bedrock is gradational. Generally, the proportion of rock fragments increases with depth while the volume of soil decreases. Shale that resists penetration (refusal) by a split-tube sampler is described as competent.

The position of the top of the Passaic formation is depicted on the "Top of Passaic Formation Structural Contour Map" (Figure 5-4) and also on the two (2) geologic cross-sections (Figure 5-6). The top of the Passaic formation is observed to range between -20 and -40 feet NGVD. The bedrock surface is somewhat variable with a well-defined trough aligned north-south beneath the center of the site.

5.2 Site-Specific Hydrogeologic Conditions

The geologic conditions beneath the site have been described in the preceding section. In this section, the manner in which the various geologic units combine to form distinct water-bearing zones is described in the context of the regional geologic setting.

5.2.1 Groundwater Occurrence

Three distinct hydrogeologic zones exist at the site (Figure 5-7), including:

- The uppermost water-bearing zone contained within the Fill and the Peat subunit of the tidal marsh deposits, termed the "overburden water-bearing zone".
- The aquitard consisting of the Organic Silt & Clay subunit of the tidal marsh deposits (where present) and the glacial till.
- The aquifer contained within the upper portion of the Passaic formation bedrock, termed the "bedrock water-bearing zone".

The site-specific groundwater conditions within the overburden and bedrock water-bearing zones have been investigated through the installation and testing of groundwater monitoring wells. Furthermore, the hydrogeologic conditions of the aquitard have been evaluated using geologic data collected within this zone and as supplemented by hydrogeologic data collected at the GAF site located immediately north of the LCP site.

The overburden water-bearing zone occurs predominantly within the fill material. The thickness of fill, where present, ranges from ~~0.7~~ 1 to 16 feet, with an average thickness of 9 ~~to 10~~ feet. The peat subunit of the tidal marsh deposits may also be considered to be a part of the overburden water-bearing unit, although it likely serves as a transitional unit with a hydraulic conductivity somewhere between that of the Fill and the glacial till deposits below.

Comment [PJT59]: SC#11

The aquitard occurs predominantly within the bottom of the tidal marsh deposits, Organic Silt and Clay subunit (where present), and the entire thickness of the glacial till. The approximate thickness of the aquitard ranges from 20 to 40 feet with the thickest accumulation occurring in the areas near LP-101 and the bedrock trough described in Section 4.2.2.

Comment [PJT60]: SC#12 – Revised Figures 5-1 and 5-7

The bedrock water-bearing zone occurs within the fractures of the competent bedrock portion of the Passaic formation. The hydraulic conductivity of the upper portion of the bedrock is increased due to the network of secondary fractures that develops as a function of the weathering process. In some areas of

the adjacent GAF site, however, more intensive weathering and/or lithologic variation have caused the fractured rock to become clay filled reducing the hydraulic conductivity.

The data indicate that the upper portion of the bedrock water-bearing zone investigated during the LCP RI behaves as a "porous medium equivalent" (EPM) from the standpoint of groundwater flow. The EPM model is based on the relatively high bedrock hydraulic conductivity (Section 5.2.2.3) indicating the development of bedrock fractures in a sufficient density so as to be interconnected and the lack of apparent anomalies in the potentiometric data. Despite the observed areal anisotropy in likely response to a slight preferential orientation of bedrock fracturing (Section 5.2.3.3), the data do not suggest the presence of fracture controlled groundwater flow in the bedrock water-bearing zone.

Comment [PJT61]: SC#15

5.2.2 Hydraulic Conductivity

Hydraulic conductivity (K) is a coefficient of proportionality that describes the rate at which water can move through a permeable medium. The hydraulic conductivity of the fill, which constitutes the main portion of the overburden water-bearing unit, and the upper portion of the Passaic formation, which constitutes the main portion of the bedrock water-bearing zone, have been determined by rising head, in-situ (slug) tests. The hydraulic conductivity test data are provided in Table 5-2 and data files output from AQTESOLV, which was used to calculate the K value, are included in Appendix B1.

5.2.2.1 Overburden Water-Bearing Zone

The hydraulic conductivity of the overburden zone is highly variable based on the slug testing conducted during the investigation (Phase I and Phase II). Slug test data from a total of 15 wells screened within the overburden water-bearing zone indicate a hydraulic conductivity that ranges from 5.6 x 10^{-7} cm/sec to 4.6 x 10^{-1} cm/sec, with a geometric mean of 1.7 x 10^{-3} cm/sec. This range of hydraulic conductivity is reflective of the wide range of grain size that characterizes the fill soil and is consistent with the geometric mean calculated for the GAF site as discussed in the Remedial Investigation Report (Eckenfelder, 1991) of 2.5 x 10^{-3} cm/sec.

5.2.2.2 Aquitard

Hydraulic conductivity data were not directly obtained for the aquitard as part of the LCP RI. However, five (5) samples of the glacial till portion of the aquitard were collected for geotechnical analysis as part of the RI at the adjacent GAF site (Eckenfelder, 1991). The samples were collected in a thin-walled Shelby tube sampler and were subjected to laboratory testing for vertical hydraulic conductivity using a flexible walled triaxial permeameter under falling head conditions. The resultant mean hydraulic conductivity was 6.9 x 10^{-7} cm/sec, presented in Table 5-2. These data are somewhat lower than the indirect estimates for hydraulic conductivity as are presented in Section 5.3.2.

5.2.2.3 Bedrock Water-Bearing Zone

Based on the slug testing performed in the ten newly installed bedrock wells as part of the Phase II RI the hydraulic conductivity of the bedrock water-bearing zone is less variable than in the fill. The hydraulic conductivity values ranged from 8.5 x 10^{-5} cm/sec to 1.1 x 10^{-3} cm/sec with a geometric mean of 2.0 x 10^{-4} cm/sec. This geometric mean hydraulic conductivity is consistent with the geometric mean of the K values calculated for the adjacent GAF site in this zone as presented in the Remedial Investigation Report (Eckenfelder Inc., 1991) of 1.2 x 10^{-4} cm/sec.

5.2.3 Groundwater Flow

5.2.3.1 Overburden Water-Bearing Zone

The potentiometric (water table) surface of the overburden zone has been defined on the basis of contemporaneous water level data obtained on various dates, as presented in Table 5-1. Potentiometric surface maps from three dates, January 8; February 13; and March 30, 2007, are presented on Figures 5-8, 5-9, and 5-10, respectively. The latter two dates correspond to a period in which the groundwater extraction system at the adjacent GAF site was operational whereas the system was turned off for a period of several weeks prior to the January 8, 2007 date.

The water table configuration, as shown, is largely controlled by the interaction of the shallow groundwater with the surface water features including South Branch Creek and the ditch located immediately south of the site. Accordingly, groundwater from the western portion of the site flows southward toward and discharges to the southern ditch. In the eastern portion of the site, groundwater flows easterly toward and discharges into the South Branch Creek. A water table mound is evident in the center of the site, located between the two ditches.

The observed configurations of the water table under pumping and non-pumping conditions at the adjacent GAF site are quite similar. An apparent difference, however, is the slightly lower elevation of the water table surface under non-pumping conditions in January (Figure 5-8) as compared to pumping conditions in February and March (Figures 5-9 and 5-10). It is not certain if this depressed water table is a result of differences in seasonal conditions (e.g., decreased amount of infiltration from precipitation) or if it is an actual manifestation of the pumping conditions.

The current observed groundwater flow patterns in the upper water-bearing zone are somewhat different from that as observed from the Phase I data collected in 2002. Since that time, remedial construction activities have occurred at the adjacent GAF site which included the construction of an overburden hydraulic barrier wall and the re-grading of the site, including the removal of a ditch system as described in Section 2.1.2. Accordingly, a component of shallow groundwater flow to the north toward a ditch on the GAF site is no longer observed which is occasionally manifested in surface ponding in north-central area of the site.

5.2.3.2 Tidal Marsh/Glacial Till Aquitard

An aquitard is defined as a saturated, but poorly permeable, geologic unit that impedes ground-water movement and does not yield water freely to wells (USGS, 1999). Therefore it is appropriate to refer to the fine-grained soils described in Section 4.2.1.2 and 4.2.1.3, which make up the tidal marsh/glacial till, as an aquitard when they coexist with the overlying permeable Fill materials. Given the observed character and hydrostratigraphic position of the aquitard, it will provide a degree of hydraulic separation between the overlying upper water-bearing zone and the underlying bedrock water-bearing zone. Hydraulic conductivities calculated from the GAF site are provided in Table 5-3.

The probable maximum hydraulic conductivity of the aquitard can be estimated using Darcy's Law (Eq. 5.1) by a comparison of an estimated vertical recharge rate through the aquitard to the observed vertical hydraulic gradient (i_v). The resultant K value represents the worst case calculation and is therefore termed K_{max}.

$$Q = K_{max}\, i_v\, A \qquad \text{Equation 5.1}$$

Where: K_{max} = hydraulic conductivity [L/T]
Q_v = vertical recharge rate [L^3/T]
i_v = vertical hydraulic gradient [dimensionless]
A = area of the aquifer through which the recharge occurs [L^2]

Solving for K_{max} results in Equation 5.2:

$$K_{max} = Q_{max}/iA \qquad \text{Equation 5.2}$$

For the purpose of this calculation the recharge flowing through a 1 cm^2 area of the aquitard will be considered. A recharge rate through the confining unit is conservatively estimated at 16 inches per year or 1.29 x 10^{-6} cm/sec (Brown and Caldwell, 2002). The vertical gradient measurements observed at four (4) well pairs (Table 5-4) are used in Equation 5.2 along with the above recharge value to estimate the K_{max} at the four select locations. This results in a range of vertical K_{max} values ranging from 2.8 x 10^{-5} to 8.6 x 10^{-6} cm/sec with a geometric mean value of 1.3 x 10^{-5} cm/sec. These values are somewhat greater than the laboratory permeability testing for the GAF site reported in Section 5.2.2.

5.2.3.3 Bedrock Water-Bearing Zone

A regionally extensive aquifer exists within the competent bedrock portion of the Passaic formation. Anderson (1968) mapped the regional potentiometric surface of the bedrock aquifer which reveals that groundwater flows regionally east towards the Arthur Kill, its ultimate point of discharge. This pattern of bedrock groundwater flow is confirmed by the measurements made in the bedrock monitoring wells on the LCP site.

The configuration of bedrock potentiometric surface is interpreted from water level data collected from the bedrock wells on five (5) separate occasions. Bedrock potentiometric contour maps of the LCP site are depicted on Figures 5-11, 5-12, and 5-13 which correspond to measurement made on January 8, February 13, and March 30, 2007, respectively. The January 8, 2007 data were collected under static, non-pumping conditions when the adjacent GAF site bedrock extraction system had been non-operational for a period of several weeks prior to this date. The latter two dates correspond to pumping conditions by the neighboring groundwater extraction system at the GAF site. In addition, the bedrock potentiometric surfaces for the combined LCP and GAF sites are depicted for January 7 and February 5, 2008 on Figures 5-14 and 5-15.

The groundwater within the bedrock water-bearing zone contains substantial concentrations of dissolved solids, most of which are naturally occurring as a result of hydraulic communication of the bedrock water-bearing zone with the brackish Arthur Kill. These dissolved solids levels, which are higher than in the upper water-bearing zone, serve to significantly increase the density of the bedrock groundwater. This high density and the relatively long water column in the bedrock wells reduce the elevation to which water will rise in the bedrock wells in comparison to the actual hydraulic head. Therefore, the bedrock water level elevations underestimate the respective bedrock heads without a correction for this relative density difference. This correction is unnecessary in the overburden wells primarily due to the relatively short water column in comparison to the bedrock wells.

A correction for density can be derived from the Ghyben-Herzberg principle (Todd, 1980). This principle serves to define the hydrostatic balance between fresh and saline waters and is represented according to Equation 5.3.

$$z = \frac{p_f}{p_s - p_f} h_f \qquad \text{Equation 5.3}$$

Where: z = the length of the water column in the well [L]

p_f = density of fresh water = 1 [unitless]

p_s = density of saline water in the well [unitless]

h_f = difference between the equivalent fresh water and saline water level measurements

Solving for h_f results in Equation 5.4

$$h_f = \frac{\rho_s - \rho_f}{\rho_f} z \qquad \text{Equation 5.4}$$

Very precise laboratory measurements were made for specific gravity in samples collected on March 30, 2007 from the water column (non-purged) within each of the bedrock wells. These data were used to convert water level data to equivalent fresh water head (Table 5-5). The resultant correction factors ranged from 0.07 to 0.68 feet. The correction factor was applied to each of the three rounds of water level measurements which were used to prepare the bedrock potentiometric contour maps presented in Figures 5-11, 5-12, and 5-13.

The corrected bedrock potentiometric surface contour map under static (non-pumping) conditions (Figure 5-11) confirms the regional pattern of groundwater flow towards the Arthur Kill. In this manner, bedrock groundwater is observed to flow in an east-southeasterly direction across the LCP site toward the Arthur Kill to which it discharges. In addition, a slight groundwater mound within the bedrock water-bearing zone is observed beneath the center of the site in the former production area that may be indicative of slightly increased groundwater recharge downward through the aquitard in this area of the site. This increased recharge may be due to natural variation in the aquitard thickness and hydraulic conductivity and/or could be increased given the large number of penetrations by building support piles.

Figures 5-14 and 5-15 present the potentiometric surface contour maps under pumping conditions of well DEW-4A, a bedrock groundwater extraction well that is part of the groundwater treatment system (GTS) at the adjacent GAF facility. The potentiometric surfaces on these maps reveal a reversal of groundwater flow in response to pumping as compared to the static bedrock potentiometric surface map (Figure 5-11). The pattern of groundwater flow is manifested as a roughly elliptical cone of depression that is oriented toward extraction well DEW-4A. This elliptical drawdown pattern demonstrates the anisotropic conditions of bedrock hydraulic conductivity, likely in response to preferential directions of the bedrock fractures. Furthermore, the areal anisotropy is consistent with the conditions observed during aquifer testing at the GAF site in which the major axes of the drawdown ellipses trend approximately N30° east with a length that is approximately three times longer than the minor axes.

The drawdown pattern revealing the anisotropic bedrock conditions is further illustrated in the bedrock potentiometric surface maps of the combined LCP and GAF sites (Figures 5-14 and 5-15). These maps reveal the presence of two, overlapping cones of depression that are centered on GAF site extraction wells DEW-2 and DEW-4A. These extraction wells are located on the downgradient side of the GAF site in the northeast and southeast corners of the property, respectively. A smaller cone of depression is located around extraction well EW-2 on the northwestern edge of the site.

The potentiometric surface contour maps demonstrate that the existing bedrock groundwater extraction system at the GAF site provides hydraulic capture of the bedrock water-bearing zone beneath nearly the entire LCP Chemicals Inc. Superfund site. The only areas in which bedrock capture is not provided are located in very close proximity to the Arthur Kill. For example, data from the new monitoring well, MW-27D, demonstrate that groundwater capture extends at least as far southeast as the closed RCRA unit on the LCP site.

An additional important observation is that bedrock groundwater flow, under pumping conditions, is observed to sweep through the western portion of the LCP site from the GAF site and then back to the GAF site to be captured by extraction well DEW-4A. This groundwater flow onto the LCP site likely originates from beneath the area of the "Old Landfill" located in the south central portion of the GAF site (Eckenfelder, 1991). Under non-pumping conditions (Figure 5-11), groundwater within the western portion of the LCP site enters the site from other properties to the southwest. The data from the existing

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bedrock monitoring well network, at the LCP and GAF sites, provides a technically rigorous characterization of the groundwater flow pattern that is established as a result of pumping from extraction well DEW-4A.

A comparison of potentiometric surfaces in the bedrock and upper water-bearing zones on corresponding dates reveals that a strong downward gradient exists across the aquitard in the entire site except for limited areas immediately adjacent to and beneath the site ditches, including South Branch Creek. Although the magnitude of the downward gradient is greater under pumping conditions at the adjacent GAF site, it exists regardless of pumping conditions. This downward gradient creates the potential for shallow groundwater to move vertically downward into the bedrock which is then captured by groundwater extraction well DEW-4A.

5.2.4 Tidal Influences on Groundwater

A tide investigation was performed to evaluate tidal characteristics in South Branch Creek and to assess the resultant influences on the shallow and deep groundwater at the site. Frequent water level data measurements were made in South Branch Creek and selected monitoring wells using water level transducer/loggers (e.g., In-Situ, Inc. Troll). Data were collected at each station at a frequency of once per hour over a period of at least five days. The water level data are presented in a series of summary hydrographs (Figures 5-16 and 5-17) and individual hydrographs are provided in Appendix B2.

5.2.4.1 Tidal Influences on Shallow Groundwater

During the Phase I investigation tidal variations from South Branch Creek were observed to have a minimal impact on shallow groundwater levels at the site. The largest observed variation is less than 0.3 feet in well MW-6, located approximately 30 feet from South Branch Creek on the eastern berm of the closed sludge lagoon. Small tidal variations were observed in two other wells, MW-7 and MW-8, which are located approximately 25 and 32 feet, respectively from South Branch Creek also on the eastern berm of the closed sludge lagoon. Water levels in other wells that were located further from South Branch Creek are generally unimpacted by tidal variations as shown in Figure 5-16.

The groundwater level measurements obtained during the tide investigation were not evaluated using the filtering method described by Serfes (1991) as described in the FOP, due to the minimal impact of tidal variations on the shallow groundwater levels.

5.2.4.2 Tidal Influences on Deep Groundwater

During the Phase II investigation tidal variations in South Branch Creek and the Arthur Kill were observed to have a greater impact on the deep groundwater levels than in the shallow zone. Of the four (4) bedrock monitoring wells that had data-logging pressure transducers, wells MW-11D and MW-23D revealed a tidal response of approximately 0.2 feet despite the fact that they are located approximately 350 and 600 feet, respectively, from South Branch Creek as shown in Figure 5-17. Interestingly, well MW-6D located immediately adjacent to South Branch Creek did not reveal apparent tidal response suggesting that bedrock fractures in the vicinity of this well communicate poorly with the tidal water bodies. Fluctuating water levels occur most often in confined aquifers, such as the bedrock water-bearing zone, and are transmitted longer distances in response to the added pressure placed by the rising tide on an aquifer already under pressure.

5.3 Surface Water Conditions

5.3.1 South Branch Creek

South Branch Creek, the only water body on Site, is a man-made brackish tidal ditch originating in the central portion of the Site and flowing east over 1,200 feet before discharging into the Arthur Kill. The

watercourse is approximately 15 feet wide at the head of the stream and becomes as wide as 30 feet on the eastern end of the Site. It has a large tidal change from low to high tide, in the range of 5 to 5.5 feet, resulting in a total drainage of South Branch Creek during low tide. South Branch Creek does not appear on USGS topographic mapping and is not mapped by the National Wetland Inventory (NWI) program.

South Branch Creek is known to have had four (4) different alignments, which have been documented on the aforementioned maps and photographs and in the "Historic Drainage Analysis" report (Brown and Caldwell, Revised October 2006). These alignments include:

Original Natural South Branch Creek. The original South Branch Creek, prior to 1947, was a natural tidal creek that existed prior to development of the Tremley Point area and placement of anthropogenic fill in the area. This original channel was progressively filled in after it was replaced by the man-made channels that were constructed since 1951 (see Figure 2-21).

Western Man-Made Channel – 1947. The portion of South Branch Creek located west of the railroad tracks was replaced by a man-made channel that looped to the south around the future LCP site from 1951 to 1966. The original natural portion of South Branch Creek located west of the railroad tracks was subsequently filled between approximately 1947 and 1952 (see Figure 2-22).

Western Man-Made Channel – 1966. The man-made channel located west of the tracks was replaced by a covered channel (flume), replacing the southern loop around the LCP site. This flume was located along the northern edge of the LCP site property (see Figure 2-23).

Eastern Man-Made Channel – 1971. The current man-made channel was constructed around 1971. It discharges to the Arthur Kill approximately 950 feet south of the former "natural" South Branch Creek channel. It is likely that this man-made channel is underlain by the anthropogenic fill into which it was constructed. The natural eastern South Branch Creek channel was subsequently filled (see Figure 2-24).

5.3.2 Off-Site Ditches

Comment [PJT63]: Ditch Report

5.3.2.1 Ditch Descriptions

The Northern Off-Site Ditch is located approximately 40 feet south of and is aligned parallel to the southern LCP property line. The ditch originates west of the intersection of Tremley Point Road and the Road to Grasselli, and north of the LRSA publically-operated treatment works (POTW). The ditch flows eastward for roughly 2,500 feet to a culvert headwall located south of LCP Building 250. The specific location of the downstream culvert outfall is unknown; however it is believed to discharge to South Branch Creek near the bend in South Branch Creek located directly east of the headwall.

The Southern Off-Site Ditch is located approximately 100 feet south of, and is aligned parallel to the southern LCP property line and the Northern Off-Site Ditch. The ditch originates within a wetland area located between petroleum bulk storage tanks owned by Phillips 66 Co. and the LRSA POTW. The ditch flows eastward for roughly 2,400 feet to a culvert headwall located south of the extended railroad alignment on the LCP property. The location of the culvert outfall is located east of the NuStar office building in a channel leading to the Arthur Kill. An unpaved access road separates the Northern and Southern Off-Site Ditches.

5.3.2.2 Physical Conditions

The depth profile of the Northern Off-Site Ditch is presented in Figure 5-19. The channel elevation is lower than the ground surface level at the LCP Site, which is roughly 7 feet NGVD at the southern LCP property boundary. The bottom of the channel slopes generally eastwards towards the headwall, with the elevation ranging from 2.57 feet at the upstream end of the study area to 1.23 feet at the headwall. The Northern Off-Site Ditch exhibits two separate characteristic areas. The 500-ft downstream segment, located immediately upstream of the headwall, exhibits a clearly defined channel where the bed is

comprised of coarse sand to cobble-sized material that appears to have been placed during construction of this man-made channel. The channel is less clearly defined further upstream where the ditch becomes a wider grassy marsh. The northern bank (LCP-side) of the ditch is steep, dropping roughly 6 feet vertically from the adjacent LCP Site. The southern bank of the ditch is more shallow rising only 2 to 3 feet from the ditch channel. Sediment thickness in the Northern Off-Site Ditch varied from none in the downstream area near the headwall to approximately 4 feet further upstream. A NuStar petroleum pipe rack is located directly over the Northern Off-Site Ditch for its entire length, which is supported by wooden piles. The pipeline is elevated roughly 5 to 6 feet over the ditch channel.

The depth profile of the Southern Off-Site Ditch is presented in Figure 5-20. The channel elevation varies between 3.2 and 0.2 feet NGVD. The depth profile of the Southern Off-Site Ditch, however, is relatively uneven with the highest elevation being found at the 31st marker, closer to the downstream end of the study area. As a result, standing water was observed in the ditch in the upstream end during low tide, even when the downstream stretches of the ditch was observed to completely drain. The Southern Off-Site Ditch is characterized by a more clearly defined channel with steep sides along both banks. The sediment material is softer and more fine-grained than found in the Northern Off-Site Ditch. The ditch is bordered by the access road on the north bank, which itself sits above the main discharge pipeline from the LSRA treatment plant. The ditch is bordered to the south by an access road servicing Conoco bulk Petroleum Storage. Sediment thickness in the Southern Off-Site Ditch varied between 0.1 feet and 1.9 feet.

The Off-Site Ditch width and sediment thickness measurements are summarized in Table 5-6.

5.3.2.3 Ditch Flow

Continuous water level measurements made in the downstream reach of each ditch (culvert headwalls) were made for a period of 5 days as presented in Figures 5-21 and 5-22. These data reveal that each ditch is tidally influenced. The lower portion of the tidal cycles in each ditch are truncated given the elevations of the respective downstream culvert invert elevations that are above sea level.

Water level elevations observed during tidal fluctuations in the Northern Off-Site Ditch ranged between 1.5 feet NGVD at low tide to 3.9 NGVD feet at high tide. Estimates of the flow velocity of the Northern Off-Site Ditch were made at the approximate midpoint of the outgoing tide at approximately 0.08 feet/second in the downstream end of the ditch. An estimateof flow velocity in the grassed marsh area of the Northern Off-Site Ditch could not be made due to the lack of a clear channel of water flow.

Water level elevations in the Southern Off-Site Ditch ranged between 0.8 feet NGVD at low tide to 3.3 NGVD at high tide. Estimates of the downstream flow velocity of the Southern Off-Site Ditch were made during the approximate midpoint of the outgoing tide ranging from 0.1 and 0.38 feet per second.

A round of synoptic groundwater levels at the LCP Site was made at the same time as continuous water level monitoring in the ditches. These data reveal that shallow groundwater along the southern border of the LCP Site flows toward and discharges into the Northern Off-Site Ditch (Figure 5-23).

5.3.2.4 Transport Pathways

The information provided above indicates there are three primary contaminant transport pathways from the LCP Site that may reach the Northern Off-Site Ditch; overland discharge of stormwater from the LCP site to the ditch, discharge of shallow overburden groundwater to the ditch, and tidal flow upward from the likely connection to South Branch Creek. Given the lack of drainage improvements along the southern property line of the LCP Site, it is likely that stormwater, and solids carried in the stormwater, would drain in the direction of the Northern Off-Site Ditch during a major storm event.

It does not appear that the Southern Off-Site ditch would receive drainage from the LCP, as the ditch is not physically connected to the Site, and the unpaved road between the ditches would act as a physical

barrier to drainage between the ditches. Additionally the Southern Off-Site Ditch is understood to receive tidal influx directly from the Arthur Kill, as opposed to South Branch Creek.

5.3.3 ~~5.3.2~~ Arthur Kill

South Branch Creek discharges into the Arthur Kill, located immediately east of the Site. The Arthur Kill is a large tidal strait that separates Staten Island from mainland New Jersey and is approximately 300-600 feet wide and greater than 30 feet deep. ~~, that flows from north to south, discharging into the Raritan Bay~~ A more detailed description of the hydrodynamic flow in the Arthur Kill is presented in Section 5.3.4. The Arthur Kill receives flow from the Site through South Branch Creek and vice versa. The Arthur Kill is frequently dredged to maintain a passageway for commercial ships. It is mapped as an estuarine, unconsolidated bottom, subtidal river [E1UBL]. According to the NJDEP, the Arthur Kill is classified as a SE3 watercourse. The SE3 classification is given to estuarine waters designated for secondary contact recreation, maintenance and migration of fish populations, migration of diadromous fish, maintenance of wildlife, and any other reasonable uses. The stretch of the Arthur Kill adjacent to the Site is classified as SD by the NYSDEC. The SD classification is for saline waters that are suitable for fish survival. This classification is given to waters that, because of natural or man-made conditions, cannot meet the requirements for primary and secondary contact recreation and fish propagation.

Comment [PJT64]: SC#16

5.3.4 ~~5.3.3~~ Hydrodynamic Flow in the New York Harbor Estuary

The LCP is located along the Arthur Kill, a large tidal straight that connects Newark Bay and Kill van Kull to the north and Raritan Bay to the south (see Section 2.4.1). The tidal flows in the Arthur Kill and the New York Harbor system are exceedingly complex and have been the subject of numerous extensive studies and associated hydrodynamic modeling efforts. These studies have largely been prompted by the need to enhance the understanding of "estuarine circulation and mixing within the New York Harbor system that are produced by wind, tidal forcing and freshwater flows as influenced by the complex coastline and topographical features".

Studies done by Blumberg, *et al.*, 1999 and Kaluarachchi, *et al.*, 2003 provide descriptions of the transport process in the New York Harbor system. In both studies a three-dimensional hydrodynamic model of the New York Harbor Region was developed to simulate estuarine circulation. The Kaluarachchi, *et al.* model is an enhanced version of the Blumberg, *et al.* model which included improvements to model geometry (i.e., longitudinal resolution of the model grid segmentation and bathymetry) and adjustments in bottom friction to improve the calibration in the Hackensack, the Passaic and the Raritan Rivers, and Newark Bay, (Kaluarachchi, *et al.*, 2003). It was found that improvements to the model calibration in the areas above, significantly improved the calibration in the Arthur Kill and Kill van Kull.

In an attempt to quantify the main forcing mechanisms that drive the transport in the Arthur Kill, Kaluarachchi, *et al.*, 2003 evaluated the fluxes and the major forcing functions. The primary forcing functions utilized in the modeling included elevation differences (hydraulic gradients), density differences caused by salinity (salt flux) and temperature differences, and meteorological functions between the following locations:

- Kill van Kull from the entrance to the Kill van Kull (from New York Harbor) and Shooters Island
- Arthur Kill from Shooters Island to Perth Amboy
- The combined Kill van Kull and Arthur Kill from entrance to the Kill van Kull (from New York Harbor) to Perth Amboy

The gradients and salt fluxes were evaluated and results showed that the flux through Arthur Kill is dominated by the elevation gradient between the entrance to the Kill van Kull (from the New York Harbor) and Perth Amboy. It was observed that these elevation gradients developed as a result of the

tidal lag between the entrance to the Kill van Kull and Perth Amboy drive the flow northwards as well as southwards through the Arthur Kill. Similar analysis performed by Kaluarachchi, *et al.*, 2003 of the density gradient against the fluxes suggests that density is not a driving factor for the salt flux through the Arthur Kill.

Both studies (Blumberg, *et al.*, 1999 and Kaluarachchi, *et al.*, 2003) show the net direction of flow and volume flux to be to the west and south. That is, the net direction of flow is from the New York Harbor, west through Kill van Kull and then finally south through the Arthur Kill. Kaluarachchi, *et al.*, 2003 recorded peak fluxes as high as 400 m^3/s in the Arthur Kill that were directed towards the Raritan Bay. The net volume flux exiting from Newark Bay is directed to the southward through the Arthur Kill. Additionally Kaluarachchi, *et al.*, 2003 concluded that fluxes through Arthur Kill can be balanced by the flux through Newark Bay and Kill van Kull within 10% accuracy. Blumberg, *et al.*, 1999 describes the volume flux in the Arthur Kill as being well mixed with depth.

In summary, the results of the studies and modeling by Blumberg, *et al.*, 1999 and Kaluarachchi, *et al.*, 2003 demonstrated that the net tidal flow and net salt flux in the Arthur Kill is southward. The majority of the tidal flow originates from the New York Harbor through the Kill van Kull although flows from Newark Bay are directed southward through the Arthur Kill as well. The highest net flows in the Arthur Kill occur during the winter months (December through March) and the lowest flows occur in late summer and early fall (August and September). Little vertical stratification was observed with respect to flows in the Arthur Kill.

5.4 Sediment

The sediment bed in South Branch Creek is composed of a wide variation of sediment types, ranging from organic to clay and silt to gravelly sediment. The banks of South Branch Creek are generally excavated into granular fill soil. Some rip-rap is present along the banks of the creek and some construction debris is present along the bottom and banks of the creek.

The sediment bed in the Northern Off-Site Ditch is separated into two distinct areas. Sediments in the upstream marshy areas were fine grained and intermixed with noticable amounts of organic material and decomposed grasses from the surrounding marsh. The sediment bed in the downstream reache consists of a mixture of sand and cobble sized material apparently put in place during the anthropogenic channelization of the ditch.

The sediment in the Southern Off-Site Ditch was uniformly loose and fine grained throughout the study area.

Comment [PJT65]: Ditch Report

5.5 Wetlands

At the Site, wetlands are located in narrow bands along the entire length of South Branch Creek and slightly west from the headwaters, west of the railroad tracks. The maximum distance of the edge of the wetlands from the water's edge in any direction is approximately 100 feet, with most zones extending 25-50 feet from the channel. The wetland swath widens as South Branch Creek approaches the Arthur Kill, with the widest area found along the southern bank of the ditch, east of the pipe bridge.

The wetlands bordering South Branch Creek have been adversely impacted due to surrounding land use. The NJDEP determined that the on-Site wetland (i.e., South Branch Creek) is of intermediate resource value, thus requiring a 50-foot regulatory buffer. However, the on-Site habitat assessment found the wetlands to be highly degraded and of relatively low habitat quality, as described in Section 5.7 below.

5.5.1 Wetland Delineation

Wetland delineation was performed by EcolSciences, Inc., (EcolSciences) in 2006, and a wetland boundary map dated September 16, 2006, was submitted to NJDEP. NJDEP approved the wetland boundaries in a Letter of Interpretation Line Verification (LOI) dated February 16, 2007. The LOI and the wetland map appear in Appendix G. In addition, the wetland boundaries are shown on Figure 5-18. The total delineated wetland area is 2.3 acres, of which 1.9 acres is surveyed on property and of which 1.0 acre is open water.

5.5.2 NWI Mapping

According to the National Wetland Inventory (NWI) digital data provided by the USFWS, one NWI wetland is mapped within the boundaries of the Site. This wetland, in the locality of South Branch Creek, is mapped as an estuarine, intertidal, emergent, mesohaline, irregularly flooded wetland [E2EM5P]. A wetland located immediately adjacent to the northwestern Site boundary is mapped as an Estuarine, subtidal, unconsolidated bottom, subtidal, excavated wetland [E1UB1x].

5.5.3 NJDEP Wetland Mapping

According to a Geographic Information System (GIS) dataset provided by the NJDEP, no NJDEP wetlands are mapped on the Site. The closest NJDEP wetland is approximately 100 feet south of the southwestern corner of the Site. This wetland is mapped as a palustrine, emergent, persistent, saturated wetland [PEM1B].

5.6 Ecology

The Chazen Companies (TCC) completed an Ecological Assessment (EA) Report for the LCP site in August 2007. The methodology utilized to complete this EA consisted of information gathered from federal, state, and local agencies, supplemented by Site visits designed to identify and characterize the Site's flora and fauna. Additionally, the Site was studied for the presence of endangered, threatened, and/or rare (ETR) species and their habitats.

The New Jersey Department of Environmental Protection (NJDEP) indicated that there are no records of any rare wildlife or plant species or ecological communities within the Site. During the EA, 79 species of plants, 42 species of wildlife, and 3 ecological communities were identified within the Site. Overall, the flora and fauna found on the Site are species typically of heavily industrialized areas within intertidal marsh ecosystems. Vegetative species found within the Site are very common to highly disturbed areas and possess no Federal or New Jersey State protection. The wetlands bordering South Branch Creek are of limited areal extent, providing minimal natural corridor and no natural floodplain. These wetlands exist solely in anthropogenic fill and with no native hydric soils. This has resulted in a poor vegetative profile. There is an absence of native woody vegetation, and the disturbance is conducive to a high degree of infiltration by non-native species. The combination of the small corridor and dominance of invasive vegetation have produced a degraded habitat with limited support for wildlife.

5.6.1 Ecological Community Types

The first ecological community type, "Urban Vacant Lot, With Structures" (upland portion of Site), is located throughout the Site and consists of exposed soil, rubble, and derelict buildings. This community type makes up most of the Site. Vegetation is sparse and consists mostly of first successional recruitment species and invasive species typically found in urban areas. Trees are generally sparse and many exist as small saplings. Shrubs account for approximately 1-5% coverage in this community. The dominant shrub species include groundsel tree (Baccharis halimifolia), staghorn sumac (Rhus typhina), and white mulberry (Morus alba). The groundlayer accounts for approximately 20-25% of this community

and is composed of common milkweed (Asclepias syriaca), spotted knapweed (Centaurea maculosa), pokeweed (Phytolacca americana), and common plantain (Plantago major).

The second ecological community type, "Successional Old Field" (Closed RCRA Unit), is bounded within the east-central portion of the Site. It consists of a capped brine sludge lagoon that has become vegetated with early successional species. The former brine sludge lagoon has a clean cover and it is a closed RCRA lagoon. Over the years, the cap has become vegetated with early successional species such as daisy fleabane (Erigeron strigosus), narrowleaf plantain (Plantago lanceolata), clover (Trifolium spp.), and brome grass (Bromus sp.). A woodchuck (Marmota monax) burrow was observed at the western edge of the former brine sludge lagoon.

The third ecological community type, "Brackish Tidal Marsh" (South Branch Creek), is located in the eastern portion of the Site and includes South Branch Creek and its banks. Vegetation within this community is dense and dominated by tall graminoids. Vegetation along the sides of the ditch consists primarily of common reed (Phragmites australis) and smooth cordgrass (Spartina alternifolia). Several bird species including a little blue heron (Egretta caerulea), green heron (Butorides virescens), and swamp sparrow (Melospiza georgiana) were observed in this community. Mummichogs (Fundulus sp.), fiddler crabs (Uca pugnax), and ribbed mussels (Geukensia demissa) were relatively abundant in the marsh. Blue crabs (Callinectes sapidus) were also noted further out in South Branch Creek, closer to the Arthur Kill.

5.6.2 Fauna

The fauna of the Site were also cataloged during the on-Site investigation. In all, 42 species of wildlife were observed during the Site visits. Six mammalian species were either observed or recognized by their sign on or within the immediate vicinity of the Site. A woodchuck burrow was observed at the former sludge lagoon; a mouse (Peromyscus sp.) nest was observed near an abandoned building; a raccoon (Procyon lotor) track was observed along the main access road through the Site; a whitetail deer (Odocoileus virginianus) was observed near the abandoned buildings; a red fox (Vulpes) was observed along the railroad tracks; and an eastern cottontail (Sylvilagus floridanus) was observed in the vicinity of the Site. No aquatic mammals or endangered, threatened, or special concern mammalian species were observed within the Site. One reptile and one amphibian species, three species of fish, and eight species of crustaceans were observed during the field investigation. On or within the immediate vicinity of the Site, 23 species of birds were observed. Thirteen of the species were observed on Site and 10 species were observed in tidal marshes within ½ mile of the Site. Associations between bird species and their corresponding preferred habitat types were noted during the investigation. All avian species observed are common in New Jersey/New York and are typically found within the communities in which they were observed.

A full list of observed species is provided in the document titled, "LCP Chemicals Inc. Superfund Site, City of Linden, Union County, New Jersey. Ecological Assessment Report", (Appendix F). No federally and/or state endangered or threatened plant species were observed within the boundaries of the Site.

Since the Site is located within the Atlantic coast migration corridor, numerous migrating land and water birds could potentially use the Site or surrounding area as a stopover/overwintering site. The Atlantic coast is regularly used by migrating birds and approximately 50 different kinds of landbirds travel this flyway. Flocks of Canada geese (Branta canadensis) and mourning doves (Zenaida macroura) were observed in mowed fields adjacent to the Site during the field investigations.

Section 6

Nature and Extent of Contamination

A comprehensive characterization of the nature and extent of contamination in site media was performed through the RI field investigation. The field investigation was performed in two phases from 2001 to 2008 with an additional investigation of the Off-Site Ditches conducted in August 2011..

Comment [PJT66]: Ditch Report

The RI field investigation included the collection of samples from soil, soil vapor, groundwater, surface water sediment, and biota as described in Section 3.4. The collected samples were submitted for laboratory analysis as described in Section 3.7. This included analyses for the Target Compound List (TCL) organic constituents plus Tentatively Identified Compounds (TICs), Target Analyte List (TAL) inorganic constituents, and hexavalent chromium. Select samples and media were analyzed for additional parameters including PCDDs/PCDFs, methyl mercury, and mercury species, and total organic carbon. Certain media such as biota were subjected to special limited analyses, e.g., co-planar PCBs and speciated arsenic. The specific laboratory analyses are described in detail in Section 3.7.

The distribution and character of the chemical contamination is presented for each site medium in the subsections that follow. When describing specific concentration values, the text uses "ND" to indicate that the constituent was not detected. The descriptions are supported by various data tables and figures. The figures include numerous constituent distribution maps that were developed using the geographical information system (GIS) as described in Section 4.4. The concentration legends for each medium are referenced to various promulgated standards or other relevant criteria, as applicable. The data reported on the tables and maps are reported to three (3) significant figures.

For ease of reference, the discussions below have been addressed by medium and contaminant class. Section 6.9 provides a site-wide summary of the nature and extent of contamination. Further integration of the data into the Conceptual Site Model is provided in Section 7.4.

6.1 Soil

Soil samples were collected during Phases I and II through the full thickness of the overburden soils that underlie the site, including a large number of surficial (0-2 ft) soil samples. The soil samples were obtained as surficial grab samples, shallow direct-push borings, deep borings by hollow-stem auger and fluid rotary drilling and horizontal borings.

The New Jersey Non-Residential Direct Contact Soil Remediation Standards (NRDCSRS) are used as benchmarks for the characterization and relative distribution of chemical constituents within surficial and subsurface soils. The NRDCSRS are promulgated remediation standards [N.J.A.C. 7:26D] that are based on theoretical exposures via accidental human ingestion, dermal contact, and/or inhalation of soils. The NRDCSRS represent concentrations below which NJDEP would not have concern about incidental human contact. The unsaturated zone soil data are also compared to default Impact to Ground Water Soil Screening Levels. These are not standards, but default guidance values intended to be used "where no site specific information is available." Since there are ample available groundwater quality data for the Site, these screening levels are simply presented for reference.

Comment [PJT67]: SC#17 – Revised Tables 6-1A – 6-1D

Soil quality maps include data from both Phase I and Phase II and are separated into the four (4) depth ranges that reflect the three (3) distinct lithologies found on the site: surficial soil (0 - 2 feet), deep anthropogenic fill (> 2 feet), tidal marsh deposits, and glacial till. In situations in which there are

multiple samples within a single lithology (e.g., deep fill) the sample with the highest constituent is displayed. The "low marsh" soils may, in part, represent the geologic surface exposure or "outcrop" of the tidal marsh deposits along South Branch Creek and are included on the constituent maps of the tidal marsh deposits. However, the low marsh soils are also separately described in Section 6.2.

The constituents, for which soil quality maps were prepared, were selected on the basis of the relative frequency of exceedances of their respective NRDCSRS and relevance as contaminants of concern as related to the site. Descriptive statistics for soil are presented in Tables 6-1a through 6-1d and the exceedances of the NRDCSRS are presented in Tables 6-2a through 6-2d, broken into the distinct layers as described above.

6.1.1 Mercury

Total Mercury

In the surficial fill soils, the total mercury concentrations ranged from non-detect to 7,870 mg/kg, with approximately 57 percent of these detections exceeding the NJ NRDCSRS of 65 mg/kg. The exceedances of the NJ NRDCSRS are presented in Table 6-2a and Figure 6-1a.

Aside from recent surficial sampling performed in May 2008, laboratory samples were not submitted for mercury analysis when samples contained visible elemental mercury. The elemental mercury was generally observed as a very fine spherical particles. Larger masses of elemental mercury have infrequently been observed on the ground surface in the vicinity of the production area in and horizontal borehole samples collected beneath the mercury cell buildings.

Elemental mercury was visually observed in 31 sample locations within the site, as presented in Table 6-3 and shown on Figures 6-1a through 6-1d. Six (6) of these sampling locations contained elemental mercury in the surficial fill only, including DC-SS19, 5K-B4, 5K-B5, 231-B5, SS-08-09, and SS-08-10. At four (4) of these sampling locations, including 5K-B3, 231-B4, 231-B6, and 231-B8, elemental mercury was present in both the surficial and deep fill, as depicted on Figures 6-1a and 6-1b. Surficial samples collected in May 2008 revealed that the highest relative concentration of elemental mercury compared to total mercury, 15%, can be found between building 231 and immediately west of building 240 in sample SS-08-07, as presented in Table 6-4. The visual occurrence of elemental mercury and the laboratory results for total mercury in borehole samples demonstrate decreasing mercury concentrations with depth. Moreover, mercury pooling at the ground surface has frequently been observed at the LCP site in apparent response to rainfall events, likely as a result of capillary action as soil pores become saturated with water (see Section 7.1.4). ~~These observations suggest that downward migration of elemental mercury as a result of its density is not a significant factor at the LCP site.~~ These observations suggest that downward migration of elemental mercury through the overburden material as a result of its density does not appear to be a primary transport mechanism at the LCP site. There is some deeper observed elemental mercury in the vicinity of the production buildings, as presented in Figures 6-1a through 6-1d, which may be attributed to downward migration along building pilings that penetrate the overburden strata.

Comment [PJT68]: SC#19

Total mercury concentrations in the deep fill, ranged from 0.063 to 2,110 mg/kg. Approximately 27 percent of the mercury detections exceeded the NJ NRDCSRS at depths ranging up to 14 feet, as depicted on Figure 6-1b. Of particular note was the presence of visible, elemental mercury observed in samples collected from the horizontal borings within the deep fill located beneath Buildings No. 230 and 240.

Total mercury concentrations tended to be lower in the naturally occurring soil units that underlie the anthropogenic fill, including the tidal marsh deposits and the glacial till. In fact, only five out of 28 tested samples of the tidal marsh deposits exceeded the NJ NRDCSRS of 65 mg/kg. It should be noted, however, that four (4) of the tidal marsh soils contained visible elemental mercury and were not analyzed

(Table 6-3 and Figure 6-1c). These samples were collected from boring MW-25D, located along the probable alignment of the former South Branch Creek channel (see Section 2.6.1), and adjacent to Building No. 231 and the former 500K tank.

The tested borehole samples collected from the glacial till did not exceed the NJ NRDCSRS for total mercury, including the samples collected beneath the production buildings from the horizontal borings. Notable exceptions, however, included two of the glacial till samples collected from horizontal borings beneath Buildings No. 240 that contained visible, elemental mercury (Table 6-3 and Figure 6-1d). These findings would suggest that mercury is normally attenuated at depth within the glacial till but may be subject to sporadic downward vertical migration along features such as building piles or fractures in the till.

Mercury Speciation

Six surficial soil samples were selected for analysis by a selective sequential extraction method after Bloom, *et al.*, 2003. Additional information regarding mercury sequestial extraction is found in the Human Health Risk Assessment (Appendix P). This is a five-step sequence of extractions that was established to separate various groups of mercury compounds into "biogeochemically" distinct categories. Accordingly, the method provides direct information regarding the relative mobility of the various mercury species and is comprised of the following extracts:

- F1 - Water soluble Hg
- F2 – "Stomach acid" soluble
- F3 - organo-chelated Hg
- F4 - elemental Hg and other Hg species
- F5 - mercuric sulfide (cinnabar)

The results of the sequential mercury testing are presented on Table 6-5. The data revealed that mercury in the tested surficial soils was present primarily in insoluble forms including elemental (metallic) mercury and mercury sulfide (cinnabar). Mercury speciation testing revealed some variability in the speciation profile of mercury in fill. In five of the six samples tested (230-B-101-0-1, DSP-101-0-1, 231-102-0-1, LP-102-0-1, and BSL-101-0-1; see Table 6-5), more than half of the mercury extracted in the later fractions (F4 and F5), indicating low mobility potential. In one sample, however (231-101-0-1), just over half the mercury extracted in the F3 fraction (potassium hydroxide, targeted to elute organo-metallic complexes, which can be more mobile than the later-extracting forms). However, the groundwater data clearly support the conclusion that mercury is not mobile. There are wells near sample 231-101-01 that contain only traces of dissolved mercury in the overburden (less than 0.5 µg/L; MW-26S) and no detectable mercury in the bedrock groundwater (MW-25D). Thus while the exact form of mercury appears to vary somewhat by location, the data overall indicate that the mercury present in these samples is not migrating vertically or partitioning into the aqueous phase.

Comment [PJT69]: SC#20

TCLP Mercury

An evaluation of the leachability of mercury from highly contaminated soils was performed as a supplemental study in May 2008. This assessment involved the collection of four (4) surficial soil samples that contained visible elemental mercury. Each sample was subjected to testing for both total mercury and TCLP mercury. TCLP testing involves the recirculation of water at a 20:1 liquid-to-solid ratio under specific, prescribed conditions (e.g., pH, temperature, time) and then measuring the resultant concentration in the leachate.

The results of the TCLP testing are presented in Table 6-6. The ratio of the TCLP mercury to the total mercury is also presented on the table. These data indicate that only a very small fraction of the available mercury in the tested samples was leached from the samples. The proportion of leached

mercury ranged from 0.01 to 1.89 percent, with an average value of approximately 0.5 percent. Furthermore, only two of the four samples exceeded the TCLP criterion of 0.2 mg/l. This means that even some samples containing visible elemental mercury would not be characterized as hazardous waste on the basis of TCLP testing.

Summary of Mercury in Soil

Elevated levels of mercury were found in the anthropogenic fill soils throughout nearly the entire site. The highest concentrations are found around the former production area near Buildings No. 230 and 240, including below the buildings, around which visible elemental mercury was also observed. Substantial attenuation of mercury was observed in the underlying natural soils, including the tidal marsh deposits and the glacial till. With the exception of two samples beneath Building No. 240, none of the glacial till samples exceeded the applicable standards.

In addition to mercury detected in analytical samples, there have been observations of visible elemental mercury on the ground surface and in soil borings. Observations of visible elemental mercury on the ground surface appear to coincide with rainfall events, suggesting the movement of mercury through pore spaces in surficial soils is due to capillary action, or with mechanical disturbance (e.g., excavation) of surficial soil. Visible elemental mercury found in soil borings have been primarily found in the fill material; however, limited instances have been observed in the tidal marsh deposits and glacial till in areas where building pilings penetrate the fill material.

Comment [PJT70]: SC#23

Mercury speciation testing revealed that most of the total mercury was present in relatively insoluble forms including mercury sulfide and elemental mercury. The insolubility of the mercury in soil indicates that it is relatively immobile in the subsurface.

Mechanisms that could affect mercury in soils and alter environmental mobility, such as volatilization, are discussed in Section 7.

Comment [PJT71]: SC#22

6.1.2 Arsenic and Other Metals

Arsenic

Arsenic concentrations in the surficial fill ranged from ND to 335 mg/kg, with a NJ NRDCSRS exceedance frequency of approximately 19 percent. The arsenic concentrations in surficial fill are presented on Figure 6-2a. While arsenic exceedances are widely distributed across the site, relatively few exceedances are observed within the former LCP production area. The greatest density of arsenic exceedances and the highest arsenic concentrations in soil were found in the western portion of the site in the former Linde Division leasehold.

The deep fill revealed arsenic concentrations that ranged from ND to 775 mg/kg, with approximately 36 percent of these exceeding the NJ NRDCSRS of 19 mg/kg. The NJ NRDCSRS exceedances in the deep fill ranged up to 16 feet in depth and were widely distributed across the site, as shown on Figure 6-2b. As with the surficial soil, the highest arsenic concentrations were located in the former Linde Division leasehold which is, in fact, higher than the concentrations in the surficial soil. Furthermore, arsenic is not specifically related to the chlor-alkali process. The headwater of South Branch Creek (the "Transect A Area") has historically received drainage from other sources, as discussed in Section 2.6.1. This included comingled wastewater and stormwater from the LCP and GAF sites. In addition, ditches located parallel to both sides of the railroad track conveyed surface drainage from the north that originated on the GAF and duPont sites. Both the GAF and duPont sites were known to have used arsenic. The arsenic present in South Branch Creek, which is heavily concentrated in the Transect A area, greatly exceeds the concentrations found in LCP site soils, further suggesting an off-site source(s).

Comment [PJT72]: SC#24

As with the surficial soil, the highest arsenic concentrations in the deep fill were located in the former Linde Division leasehold where concentrations were higher than in the surficial soil. Furthermore, arsenic is not specifically related to the chlor-alkali process. There is no history of arsenic use at the Linde Division, although arsenic presence may be related to the placement of anthropogenic fill in preparation for the construction of a Central Railroad Company of New Jersey railroad yard prior to 1940 (see Section 2.1.1).

Arsenic was detected in all but one of the tidal marsh deposit samples at concentrations ranging from ND to 437 mg/kg. Approximately 35 percent of the samples exceeded the NJ NRDCSRS of 19 mg/kg (Figure 6-2c). The highest levels of arsenic in subsurface tidal marsh soils occur in the area of the former Linde Division leasehold.

Arsenic was ND in more than half of the tested glacial till samples. No exceedances of the NJ NRDCSRS for arsenic were observed in the glacial till (Figure 6-2d).

Other Metals

A relatively small number of exceedances of the NJ NRDCSRS were observed for other metals, including cadmium, cobalt, lead, and zinc as presented on Tables 6-2a through 6-2d. These higher concentrations were primarily observed in the anthropogenic fill. Many of the soil samples that exceeded the NJ NRDCSRS for lead were detected within a small well defined area of the Linde Division leasehold. Barium was used in the brine sludge process, where it entered the process as barium sulfate and was converted to barium chloride. Barium's presence is therefore site related. However, barium was not detected above the NRDCSRS in any of the 91 surficial soils samples analyzed and is therefore not a key site COC. Each metal was substantially attenuated at depth in all areas of the site. There were no exceedances of other metals in the underlying glacial till.

Comment [PJT73]: SC #26

Arsenic and Other Metals Summary in Soil

The ubiquitous presence of arsenic and various other metals in areas with no production history, their distribution within the anthropogenic fill without a decreasing concentration gradient, and the absence of an association with the known sources of contamination lead to the conclusion that the occurrences of arsenic and other metals are not associated with site operations; rather they are associated with the presence of anthropogenic fill materials and off-site sources. ~~The elevated concentrations of these metals is consistent with the Department's historic fill database maximum and average values [N.J.A.C. 7:26E-4.6] as presented in Table 6-7.~~

Comment [PJT74]: ES#1 – Remove Tables 6-7, 6-8

~~A small number of site samples did exceed the historic fill database maximum values for lead, zinc, and benzo(a)anthracene, as presented on Table 6-8.~~ This point is made simply to illustrate the prevalence of these metals in anthropogenic fill not as a result of site-specific manufacturing processes. These exceedances were largely related to the elevated levels of arsenic and several other metals, including lead, that were observed in the anthropogenic fill predominantly in the former Linde Division leasehold area.

Concentrations of arsenic and other metals in the underlying natural soils were substantially attenuated with respect to the anthropogenic fill. In fact, relatively few metals exceedances were observed in the tidal marsh deposits. Furthermore, nearly all of the exceedances of arsenic and other metals in the tidal marsh deposits occur within the western portion of the site. This distribution differs from that of mercury, which was concentrated in the former chlor-alkali facility production areas.

No exceedances of arsenic or metals, including mercury, were observed within the glacial till.

6.1.3 PCBs

Polychlorinated biphenyls, or PCBs, are a class of organic compounds with 1 to 10 chlorine atoms attached to biphenyl. Theoretically, 209 separate PCB congeners can exist, although only about 130 congeners typically occur in commercial PCB mixtures. Commercial PCBs are referred by their trade name "Aroclor," mixtures that usually contain 50 or more PCB congeners. PCB Aroclors were analyzed for in each of the soil samples.

Aroclor 1254 was the predominant PCB mixture detected within site soils, with Aroclor 1260 occurring less frequently. No other PCB Aroclors were detected on the site. The spatial distribution of the sum of Aroclor 1254 and 1260 is depicted for each of the four (4) depth intervals on Figures 6-3a through 6-3d. Total PCB concentrations (sum of each of the seven individual Aroclors) were compared to the NJ NRDCSRS for total PCBs of 1 mg/kg. As shown on Figure 6-3a, numerous exceedances of the NJ criterion were observed in surficial soil, particularly around the former LCP production area. While 21 percent of the surficial soil samples exceeded the NJ NRDCSRS, the total PCB concentrations were relatively low compared with other regulatory limits. Only one sample in the surficial soil (230-B4), located east of Building 230 in the former rectifier area, exceeds the USEPA Toxic Substances Control Act (TSCA) criterion of 25 mg/kg for soil decontamination in restricted access (industrial) areas per the PCB Rule [40 CFR Part 761.125].

PCBs were undetected (ND) in ¾ of the tested deep fill samples. Total PCB concentrations in the deep fill ranged from ND to 43.2 mg/kg. In the deep fill interval, total PCB concentrations exceeded the 1 mg/kg NJ NRDCSRS in 9 percent of the samples. The 25 mg/kg USEPA criterion was only exceeded, however, in one sample (Aroclor 1254 in 231-B6, located at the southwest corner of Building 231). There were no exceedances of the 1 mg/kg NJ NRDCSRS criterion in samples collected from the tidal marsh deposits or the glacial till.

Aroclor 1254 and Aroclor 1260 were the primary commercial mixtures that were used in electrical equipment in the US around 1950 (Fiedler, 1997). PCBs are not directly related to the chlor-alkali process. It is likely, however, that electrical equipment used at the site was the source of these PCBs in soil given the distribution of PCBs in the surficial soils around the production area. The data suggest, however, that likely PCB spills from electrical equipment were relatively modest given the relatively low concentrations and the fact that they have not penetrated to any substantial degree in subsurface soils.

6.1.4 Polychlorinated Naphthalenes

Polychlorinated naphthalenes (PCNs) are a group of halogenated compounds that are considered to be "dioxin like". They consist of two fused benzene rings, or naphthalene, with one to ten chlorine atoms attached. Commercially available PCNs are mixtures of 75 chlorinated naphthalene congeners and byproducts.

It is possible that the detected PCNs at the site may be related to reactions between the chlorine and the graphite anodes. However, the PCNs present in site soils include only the mono, di-, and tri-chlorinated congeners as presented on Table 6-9. The more toxicologically significant higher chlorinated congeners (penta through hepta) that are of concern at other chlor-alkali sites are not detected at the LCP site. The higher chlorine group congeners would have been detected on the TIC scan if they were present. The analytical laboratory took specific steps to run the GC/MS for sufficient time to allow the higher-chlorine PCNs to elute. The total PCN concentrations ranged from 0.007 mg/kg to 76.8 mg/kg in the surficial fill and 0.012 mg/kg to 19.2 mg/kg in the deep fill. Although low levels of PCNs were also detected in several tidal marsh deposits and glacial till samples, the concentrations were considerably lower than detected in shallower soils.

6.1.5 Polycyclic Aromatic Hydrocarbons

Polycyclic Aromatic Hydrocarbons (PAHs) are a class of compounds comprised of fused aromatic rings in a variety of structural configurations. PAHs can be formed as products of the incomplete combustion of organic materials and are present in considerable quantities in fossil fuels, including coal, fuel oil, and diesel fuel. Sources of PAHs in soil include emissions from power plants and domestic heating systems that burn oil, coal or wood, gasoline and diesel engine emissions, emissions from waste incineration facilities, and various industrial activities. Accordingly, fill containing combustion residues often contains considerable levels of PAHs. Table 6-10a through -10d and Figures 6-4a through 6-4d presents the sum of the 18 TCL PAHs analyzed in site soils.

PAHs are hydrophobic compounds, and their persistence in the environment is due in large part to their low water solubilities and resistance to biodegradation. Higher-molecular weight PAHs exhibit a greater environmental persistence than lower-molecular weight PAHs due to an increase in hydrophobicity and an increasing resistance to biodegradation as the molecular size of the PAHs increases (up to four or five fused benzene rings). The higher-molecular weight PAHs are more commonly associated with coal or coal by products, including bottom and fly ash, whereas the lower-molecular weight PAHs are more closely associated with petroleum products (see table below).

Low-molecular weight PAHs (2- and 3-ring structures)	High-molecular weight PAHs (4-, 5-, and 6-rings)
Acenaphthene	Benz[a]anthracene
Acenaphthylene	Benzo[a]pyrene
Anthracene	Benzo[b]fluoranthene
Fluorene	Benzo[ghi]perylene
Naphthalene	Benzo[k]fluoranthene
2-Methylnaphthalene	Chrysene
2-Chloronaphthalene	Dibenz[a,h]anthracene
Phenanthrene	Fluoranthene
	Indeno[1,2,3-cd]pyrene
	Pyrene

The high-molecular weight PAHs were frequently detected in the soils and occur across the entire site, including areas with no production history. The frequency of detection in the deep fill (> 2ft) for these constituents ranged from 7 percent (dibenzo(a,h)anthracene) to 74 percent (fluoranthene). The NJ NRDCSRS were infrequently exceeded by the high-molecular weight compounds.

The low-molecular weight PAHs were also detected frequently and occur across the entire site, including areas with no production history. The range for this group of PAHs in the deep fill (> 2 ft) was from a low of 6 percent detections (acenaphthylene) to a high of 68 percent (phenanthrene). The NJ NRDCSRS for the low-molecular weight PAHs were not exceeded.

These observations lead to the conclusion that the PAHs are primarily associated with anthropogenic fill materials and are not the result of site operations. ~~The maximum target contaminant concentration in typical historic fill [N.J.A.C 7:26E, Appendix D] for benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, and dibenzo(a,h)anthracene are provided in Table 6-7. It should be noted that only a single sample located north of the production buildings for a single PAH (benzo (a) anthracene) exceeds the maximum target concentration for a PAH (Table 6-8).~~

Comment [PJT75]: ES#1

Carcinogenic PAHs

Eight (8) specific, high-molecular weight PAHs are designated by USEPA as possible human carcinogens. Benzo(a)pyrene (B(a)P) is the most completely studied of the possibly carcinogenic PAHs (cPAHs) and exhibits the highest relative toxicity. Toxic Equivalency Factors (TEFs) are assigned to these cPAHs relative to the carcinogenic potency factor of B(a)P by USEPA (1993) based on the risk of oral exposure, as presented in Table 6-11. The TEFs are used to develop a Toxicity Equivalency Quotient (TEQ) which is the sum of the quantity of individual cPAHs respective TEF. TEQs allow the comparison of the relative risk of exposure in areas of contamination that vary widely in the composition and level of cPAHs.

A summary of the resultant TEQ values is presented in Tables 6-12a through 6-12d and shown in Figures 6-5a through 5d and Figures 6-6a through 6d. Map pairs of cPAHs are presented for each depth interval. The first map in each pair presents a graphical representation of the relative concentration of each cPAH and lists the total cPAH concentration in the sample. The second map in each pair presents a graphical representation of the relative cPAH TEQ. As with the PCDDs and PCDFs described below, the TEQs are used here to describe the geo-spatial distribution of these compounds and not to represent risk.

The figures reveal that most of the cPAHs were found in the anthropogenic fill layers. This is not surprising, given the likely presence of PAHs at the site as a result of anthropogenic fill placement. cPAHs were infrequently detected in the tidal marsh deposits, except where they were exposed as “low marsh” soils along South Branch Creek. The cPAHs were not detected in the underlying glacial till except beneath the production buildings in which they may have migrated downward along the numerous timber building piles.

The cPAH data revealed that most samples contained relatively even proportions of each of the eight (8) cPAHs, with only a few exceptions in which a single cPAH predominates (e.g., benzo(a)anthracene in the surficial sample at TLS-11).

The cPAH TEQs ranged from non-detectable to a high of 102 mg/kg. The cPAH TEQs are widely distributed across the entire site with no apparent pattern of distribution. The cPAH TEQ values are no higher in the former LCP production area than in any other area of the site. This distribution provides additional evidence of the presence of PAHs as a result of anthropogenic fill.

6.1.6 PCDDs/PCDFs

Polychlorinated dibenzo-p-furans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs) are groups of halogenated organic compounds. There are 210 possible structural congeners of PCDF and PCDD. Of these, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) has been shown to be the most toxic. In addition, PCDF and PCDD congeners, in which the lateral 2, 3, 7, and 8 positions are occupied with chlorines (2,3,7,8-substituted congeners), are acknowledged to have a higher relative toxicity than the other congeners (i.e., non-2,3,7,8-substituted congeners).

PCDDs and PCDFs can be formed as by-products in the manufacture of organochlorides, during the incineration of chlorine-containing materials, in the bleaching of paper, and from natural sources such as volcanoes and forest fires (Beychok, 1987). The major current and historical sources of PCDDs and PCDFs include coal fired utilities, municipal waste incinerators, metal smelting, diesel trucks, land application of sewage sludge, burning treated wood, and backyard trash burn barrels (USEPA, 2005).

PCDFs and PCDDs in soils were tested as a part of this investigation in approximately 10 percent of the samples during Phase I and II.

Seventeen (17) specific PCDDs/PCDFs have been assigned Toxic Equivalency Factor (TEFs) by the World Health Organization (WHO, 2005) and these have been adopted by USEPA. The TEFs are based on the chemical’s toxicity relative to 2,3,7,8-TCDD, with the toxicity of 2,3,7,8-TCDD being equal to 1.0. The

Comment [PJT76]: SC#27

TEFs are used to develop a Toxicity Equivalency Quotient (TEQ) which is defined as "the sum of the quantity of individual PCDD/PCDF congeners multiplied by the respective TEF." TEQs allow the comparison of the relative risk of exposure in areas of contamination that vary widely in the composition and level of PCDDs/PCDFs. The TEQs are used here to develop a single concentration expression for each sample for the purpose of evaluating the nature and extent of the PCDD/PCDF distribution. These TEQ sums are not intended to represent risk from contact with soils. A summary of the resultant TEQ values is presented in Table 6-13 and shown in Figures 6-7a through 6-7d.

Very low levels of PCDDs and PCDFs were detected in each of the samples analyzed, as presented in Table 6-13. Each of the TEQs were less than 1.0 µg/kg (ppb), ranging from 0.00002 to 0.885 µg/kg. The highest TEQs, which were largely driven by the PCDFs, were observed in the surficial soils, particularly in two samples collected immediately east of Building No. 231 (Samples No. LP-10 and LP-16). Substantial attenuation of TEQ concentrations was observed with increasing depth (Figures 6-7a through 6-7d).

There is some evidence as reported in the literature that PCDDs and particularly PCDFs may be present in the mercury sludge at chlor-alkali sites as a result of the reactions between the chlorine and the graphite anodes, as may be the case in Samples No. LP-10 and LP-16. This is revealed by the higher levels of total CDFs in these samples and the higher relative proportion of the tetra-CDFs and penta-CDFs and lower relative proportion of the octa-CDFs compared to the other site samples.

The PCDDs are not likely to have resulted from site sources. The distribution of PCDD concentrations in the other surficial soils is very heterogeneous, based both on specific concentrations of the various congeners and on the TEQs (Figure 6-7a). This heterogenacity and widespread distribution across the site is not apparently related to the former production area and is likely attributed to regional background conditions. While some of the PCDFs in the soil appear attributable to site operations, much of the PCDFs on the site are due to background conditions, particularly in the areas distant from the production area. The background sources likely include atmospheric deposition on the ground surface as a result of the formation of PCDDs and PCDFs from the various potential sources described above.

6.1.7 Hexachlorobenzene

Hexachlorobenzene (HCB) is a chlorinated hydrocarbon that was formerly used as a fungicide and is frequently produced as an unintended byproduct from various manufacturing processes. HCB is documented to have been produced as a byproduct in chlor-alkali plants through the reaction of the chlorine with the graphite anodes (Environment Canada, 1993).

HCB at the site was generally detected only in the anthropogenic fill with the highest levels being found in the surficial fill in the area of the former production area. Accordingly, the presence and distribution of HCB in soils appears to be related to the chlor-alkali manufacturing process at the LCP site.

HCB concentrations in the surficial fill ranged from ND to 1,440 mg/kg, with 16 percent of these samples exceeding the NJ NRDCSRS of 1 mg/kg for HCB. The exceedances occurred near Building 250, east of the tank car reconditioning shed, west of Building 240 along the former alignment of South Branch Creek, west of the sodium hydroxide tanks, near the bullet tanks, around Building 231, near the closed RCRA unit, and in the western area of the site away from the process areas. The distribution of HCB in surficial fill is presented on Figure 6-8a.

In the deep fill, HCB concentrations ranged from ND to 44 mg/kg. The NJ NRDCSRS exceedance frequency for hexachlorobenzene was 4 percent, with exceedances occurring near the "Ditch Bridge Area" along former South Branch Creek area located east of the electrical switchyard and by Building 231, as presented on Figure 6-8b.

HCB exceedances of the NJ NRDCSCC were not observed in either the tidal marsh deposits or the glacial till (Figures 6-8c and 6-8d).

6.1.8 Other Organic Compounds

A number of other organic compounds revealed infrequent exceedances of their respective NJ NRDCSRS. Only benzene (presented in Figures 6-9a through 6-9c) , hexachlorobenzene, methylene chloride and hexachlorobutadiene exceeded the criteria in greater than 1 percent of samples in any depth interval.

Chlorobenzene

Chlorobenzene is a VOC that is not generally related to chlor-alkali manufacturing but was detected within the soils, albeit at concentrations less than the NJ NRDCSRS~~CC~~ of 7,400 mg/kg. Chlorobenzene was used in manufacturing operations at the adjacent GAF and NOPCO chemical manufacturing sites. However, chlorobenzene in soils is not at sufficiently elevated concentrations to explain its presence in overburden groundwater. While not widely distributed across the site, chlorobenzene was detected in the deep fill in MW-24S at the Ditch Bridge Area along the former alignment of South Branch Creek and immediately south of Building 231 (Figures 6-10a and 6-10b). These locations are along the historic alignment of drainage from the GAF site, as discussed in Section 2.6.1. Furthermore, chlorobenzene was detected in the subsurface tidal marsh deposits south of Building 231 and in the surficial low marsh soils along South Branch Creek including near well MW-6S (Figure 6-10c).

BTEX

The presence of benzene in the soil appears to be related in many cases to "BTEX" constituents that include benzene, toluene, ethylbenzene, and xylenes, as summarized on Table 6-14a through 6-14d The toluene, ethylbenzene, and xylenes, however, do not exceed the respective NJ NRDCSCC values. The BTEX is present primarily in anthropogenic fill soils and is likely due to spills of fuel or oil on the ground or was present in the fill prior to placement.

Miscellaneous Organic Compounds

Several other organic compounds exceeded their respective NJ NRDCSCC primarily in the anthropogenic fill. These exceedances were primarily observed south of Building 231 and include benzene (Figures 6-9a to Figure 6-9c), hexachlorobutadiene, and tetrachloroethene. Methylene chloride had four exceedances of its criterion, including three near the "Ditch Bridge Area" along the former adjacent South Branch Creek and one north of Building 231. These other organic compounds are not known to be related to manufacturing operations at the site. Some of these other organic compounds were widely used in manufacturing processes at the adjacent GAF site which may be the source within the anthropogenic fill.

Residual Organic Saturation

Visual identification of possible residual saturation of unidentified organic liquids were made in a number of soil samples, as listed on Table 6-15, as were generally characterized by the presence of oily material smudge. This material is not widely distributed across the site. The soil laboratory analysis data yields no additional information regarding this material. In addition, no free phase liquids were observed in monitoring wells.

6.1.9 Tank Contents Sample

As part of the tank assessment, a single sample of the contents of the 150,000 gallon brine tank was taken as part of the Phase II field investigation. The results of this sample are presented in Table 6-16.

6.2 Low Marsh Soil

The "low marsh" soil represents narrow bands of soil located along the margins of South Branch Creek that is generally fine-grained and with a high organic content. This material likely represents sediment that has been deposited along the bank. The low marsh soils may also represent, in part, the geologic surface exposure, or "outcrop," of the tidal marsh deposits. Accordingly, the low marsh soils were also presented on the aforementioned constituent distribution maps for the tidal marsh deposits.

Ninety chemical constituents were detected in the surficial (0-0.5-foot) low marsh soil samples collected along South Branch Creek and 70 chemical constituents were detected in the low marsh soil samples collected along the Arthur Kill at the confluence with South Branch Creek. Table 6-17 summarizes the descriptive statistics of detected constituents in low marsh soil samples, and Tables 6-18a through 6-18c present the data compared to NJ NRDCSRS, the Effects Range – Low (ER-L), and Effects Range – Median (ER-M) screening values (Long, *et al.*, 1995), respectively.

The horizontal and vertical delineation of site-related constituents for low marsh soil is adequate to perform the analysis and selection of remedial alternatives as part of the Feasibility Study (FS). Additional delineation of low marsh soil may be performed, as necessary, as part of a Pre-Design Investigation (PDI).

Comment [PJT77]: GC#3

6.2.1 Mercury

Figure 6-11 shows the spatial distribution of mercury in low marsh soil. Mercury was detected in each of the 20 low marsh soil samples collected along South Branch Creek; up to 3,050 mg/kg (Table 6-17, Figure 6-11) at Transect C, near the midpoint of South Branch Creek. The NJ NRDCSRS of 65 mg/kg for mercury was exceeded in 80 percent of the samples; the ER-L and ER-M sediment screening criteria were exceeded in all of the samples. In the four low marsh soil samples collected along the Arthur Kill, all observations were below the NRDCSRS and above the sediment screening criteria, with a maximum concentration of 25.8 mg/kg. The presence of mercury in the low marsh soil is consistent with and generally related to its presence in sediments, as discussed further in Section 6.6.

Methyl Mercury

Methyl mercury was detected in each of the 20 low marsh soil samples collected from South Branch Creek and in all four of the low marsh soil samples from along the Arthur Kill (Table 6-19). The maximum concentrations were 0.1 mg/kg in the South Branch Creek samples and 0.0259 mg/kg in the samples collected from the Arthur Kill area. However, the percentage of methyl mercury as a function of total concentration was low in all of these samples: the maximum proportion of methylated was 0.13 percent in South Branch Creek and 0.1 percent in the Arthur Kill.

6.2.2 Other Metals and Arsenic

Other than mercury, 18 other metals and arsenic were detected in the low marsh soil samples collected in South Branch Creek (Table 6-17). Arsenic, cadmium and lead concentrations exceeded NRDCSRS and all elements exceeded respective ER-Ls and ER-Ms (Tables 6-18a through 6-18c). The frequency of concentrations exceeding the NRDCSRS in South Branch Creek low marsh soil samples ranged from 5 to 75 percent.

Arsenic levels were particularly elevated in the low marsh soil samples collected at the head end of South Branch Creek (Figure 6-12) consistent with the sediment results (Section 6.6.2). In addition to receiving historic discharge from the LCP site, this area receives stormwater drainage from a swale running parallel to the railroad track from the north. Historically, this swale would have carried stormwater that originated, in part, from the duPont and GAF sites located northeast of the LCP site. These detections do not likely result from LCP site sources as they were considerably higher than arsenic

levels observed in site soils within the former LCP production area. Arsenic is not related to chlor-alkali manufacturing facilities.

Arsenic, which is not related to chlor-alkali manufacturing operations, is present in upland surficial fill at an average concentration of 16 mg/kg (maximum 335 mg/kg). Arsenic is relatively heterogeneously distributed in the fill (see Figures 6-2a and b) and shows no "hot spots" or other areas with elevated arsenic (with the exception of a few locations in the Linde area on the western portion of the site, which is not close to South Branch Creek). The low marsh and sediment soils, however, exhibit much higher arsenic concentrations: up to 5,460 in low marsh soils and up to 4,250 mg/kg in sediments. These concentrations cannot be explained by the presence of low-level arsenic throughout the upland fill areas of the site.

Comment [PJT78]: SC#42

In low marsh soil along the Arthur Kill, 18 elements other than mercury were detected, 11 of which have NRDCSRS. Only arsenic concentrations exceeded the NJ NRDCSRS (in 25 percent of the samples). Almost all elements were present at higher concentrations in the low marsh soil samples from South Branch Creek than from the Arthur Kill. Arsenic concentrations were a 100-fold higher; cadmium, barium, lead and zinc had 10-fold higher concentrations.

6.2.3 Organics

6.2.3.1 PCBs

The total Aroclors found in low marsh samples are presented in Figure 6-13. Only one PCB mixture (Aroclor 1260) was detected in one of the Low Marsh Samples in South Branch Creek, at a concentration of 0.356 mg/kg Table 6-17). Aroclor 1260 was also detected in two of the low marsh samples collected from the Arthur Kill in the same concentration range. No other PCB Aroclors were reported. Individual Aroclors do not have NJ NRDCSRS established for them, but there is a NJ NRDCSRS for total PCBs of 1.0 mg/kg, which was not exceeded in any of the samples. The detection of Aroclor 1260 exceeded the NJ NRDCSRS for total PCBs. This sample was the only one in South Branch Creek that exceeded the ER-L and ER-M of 0.023 and 0.18 mg/kg, respectively.

6.2.3.2 PAHs

Of the 18 SVOC TCL chemical constituents analyzed and classified as PAHs, 15 were detected in low marsh soil samples of South Branch Creek. In Arthur Kill low marsh soil samples, 14 PAHs were detected (Table 6-17). The frequency of detection of PAHs in South Branch Creek samples ranged from 5 to 100 percent. In the Arthur Kill samples, 25 to 100 percent contained detectable PAHs. NJ NRDCSRS have been established for 10 PAHs, and ER-Ls/ER-Ms for 16. Six of the South Branch Creek and two Arthur Kill low marsh soil samples exceeded the NRDCSRS for B(a)P (Table 6-18a). ER-Ls for all compounds were exceeded (various locations in both South Branch Creek and the Arthur Kill) (Table 6-18b), but ER-Ms were only exceeded for phenanthrene and pyrene (Table 6-18c), and only in one location (Transect D).

Table 6-20 and Figure 6-14 present the sum of the 18 analyzed PAHs in South Branch Creek and the Arthur Kill. In both there was considerable inter-sample variability, but South Branch Creek and the Arthur Kill had similar average total PAH concentrations, in the range of 2-3.26 mg/kg. Figure 6-15 shows the compound-specific distribution of the carcinogenic PAHs. The array of compounds is similar in all samples areas, with a predominance of fluoranthene and pyrene. In addition, benzo(g,h,i)perylene was also predominant in the Arthur Kill and benzo(k)fluoranthene in South Branch Creek. Figure 6-16 presents the B(a)P equivalents for Low Marsh soil. Only two samples, both at Transect D, had total PAH concentrations above the ER-L of 4 mg/kg; none exceeded the total PAH ER-M of 45 mg/kg. PAHs were detected at concentrations within the same order of magnitude for both South Branch Creek and the Arthur Kill.

As described previously in Section 6.1.6, the ubiquitous presence of PAHs in soil samples collected on site is a result of their presence in the anthropogenic fill. Furthermore, the presence of PAHs is common within sediments of industrialized waterways, such as the Arthur Kill. Accordingly, PAHs in the low marsh soils are attributable to sources other than the LCP site.

6.2.3.3 Other Organic Compounds

PCDDs/PCDFs

The low marsh soil samples were analyzed for 17 PCDDs/PCDFs, 21 pesticides and herbicides, 51 non-PAH SVOCs, and 46 VOCs. Each of the low marsh soil samples collected from South Branch Creek and the Arthur Kill contained detectable dioxins and furans (all analyzed compounds) (Table 6-17). ~~The geometric mean of the TEQs in South Branch creek was 58 pg/g, lower than the concentration in the one sample from the Arthur Kill area (223 pg/g).~~ While there is a high total TEQ found in Transect C, the remaining samples collected along South Branch Creek revealed a significantly lower total TEQ than the sample taken along the Arthur Kill (223 pg/g). Table 6-21 shows a summary of individual sample results for PCDDs/PCDFs and TEQs in low marsh soil. The PCDD/PCDF TEQ results are presented in Figure 6-17. As discussed previously in Section 6.1.8, PCDFs are attributed in part to site operations, as reflected in the predominance of PCDFs in the TEQ in landward low marsh soils. Low marsh soils near the Arthur Kill reflect a greater TEQ contribution of PCDDs from regional sources. This pattern of regional contamination, attributable to regional influences, is similar to that observed in sediment (see Section 6.6.3.3).

Comment [PJT79]: SC#28

Pesticides/Herbicides

Four pesticide and herbicide compounds were detected in the South Branch Creek low marsh soils (Table 6-17), with a detection frequency ranging from 15 to 95 percent. In the Arthur Kill, six pesticide and herbicide compounds were detected, ranging from 25 to 100 percent detection frequency. All concentrations were the same order of magnitude. NJ NRDCSRS have been established for 16 pesticide and herbicide compounds, but none of the low marsh soil samples exceeded respective values. ER-Ls/ER-Ms (available for nine pesticide compounds) were also not exceeded.

PCNs

PCNs were not detected in the low marsh soil samples.

Other Organic Compounds

Of the non-PAH SVOCs analyzed, 10 were detected in the low marsh soil samples from South Branch Creek and two in the Arthur Kill samples. Seven VOC compounds were detected in the South Branch Creek low marsh soils and two in the samples collected from the Arthur Kill low marsh soils. As with sediments, VOCs were generally trace: with the exception of chlorobenzene (maximum detected 120 mg/kg, vs. the NRDCSRS of 7400 mg/kg), all other observations were below 3 mg/kg.

Ten non-PAH SVOC compounds were detected in South Branch Creek low marsh soil samples. The detection frequency for these ranged from 5 to 80 percent (Table 6-17). Two SVOCs (bis(2-ethylhexyl phthalate and carbazole) were detected in the Arthur Kill, with a detection frequency of 25 and 75 percent. NRDCSRS have been established for 29 of the analyzed non-PAH SVOC compounds, but none of the low marsh soil samples exceeded respective values. All detected SVOCs had concentrations in the same order of magnitude.

Hexachlorobenzene was detected at low concentrations in only two of the tested samples. The concentrations of 0.047 and 0.175 mg/kg and did not exceed the NJ NRDCSRS of 1 mg/kg. The NJ lowest sediment screening value (used as ER-L by the NJDEP) of 0.020 was exceeded in both samples, but the higher NJ screening value of 24 mg/kg (used as the ER-M) was not.

6.3 Soil Vapor

Soil vapor samples were collected from shallow soil vapor probes as shown on Figure 3-2. Samples from ten (10 probes) were tested for VOCs. Samples from four (4) probes were tested for mercury vapors. The statistical summary of the data are summarized on Table 6-22.

The delineation of site-related constituents for soil vapor is adequate to perform the analysis and selection of remedial alternatives as part of the Feasibility Study (FS). Additional delineation of soil vapor may be performed, as necessary, as part of a Pre-Design Investigation (PDI).

Comment [PJT80]: GC#3

6.3.1 Mercury

Mercury vapors were detected in each of the four (4) samples that were tested. The concentrations ranged from 0.2 to 2.5 µg/m3. ~~There is no screening level for elemental mercury for either the residential or non-residential soil gas samples.~~ There are no NJDEP Soil Gas Screening Levels for elemental mercury (NJDEP, March 2013). However, none of these values exceed the Draft Vapor Intrusion Guidance value of 3 ug/m³ (USEPA, November 2002) that correspond to a hazard of 1. There are no detections of mercury in the samples above this screening level.

Comment [PJT81]: SC#29 – Revised Table 6-22

6.3.2 Volatile Organic Compounds

The VOCs detected in the soil vapor are similar to those that were detected in the soil. The VOCs in soil vapor include chlorobenzene, BTEX compounds, hexachlorobutadiene, chloroform and TCE. A comparison to New Jersey Soil Gas Screening Levels-Non-Residential (NJSGSLNR, NJDEP, March 2013) reveals a total of 11 ~~15~~ exceedances (Table 6-23) of five separate constituents (Hexachlorobutadiene, TCE, PCE, Carbon Tetrachloride, ~~Benzene~~, and Chloroform). The exceedances were from various soil vapor probes located along the railroad tracks and the western portion of the site, as well as the central portion west of Building Nos. 230 and 240.

Comment [PJT82]: SC#30

6.4 Groundwater

Two (2) rounds of groundwater quality samples were collected from monitoring wells at the site. These included one (1) round each of the complete group of wells that were available during each phase of the investigation. The Phase I round included the collection of samples from a total of 15 overburden wells in December 2001. The Phase II groundwater data comprised the sampling from 19 overburden and 10 bedrock monitoring wells between January and March 2007.

The horizontal and vertical delineation of site-related constituents for groundwater is adequate to perform the analysis and selection of remedial alternatives as part of the Feasibility Study (FS). Additional delineation of groundwater may be performed, as necessary, as part of a Pre-Design Investigation (PDI).

Comment [PJT83]: GC#3

6.4.1 Groundwater Quality Criteria

As discussed in section 2.8.2, the New Jersey Class IIA groundwater quality standards (GWQS) [N.J.A.C. 7:9C] are used as benchmarks for the characterization of overburden groundwater. Comparisons of site-specific overburden groundwater quality data to the Class IIA GWQS are provided in Tables 6-26A and 6-27A and in the following text sections.

Comment [PJT84]: GC#2

While the bedrock groundwater has been granted III-B reclassification, no specific procedure that is acceptable to NJDEP currently exists to develop alternate groundwater quality criteria for Class III-B aquifers. In order to be protective of surface water in the Arthur Kill, to which the bedrock groundwater discharges, the New Jersey Surface Water Quality Standards (SWQS) [N.J.A.C. 7:9B] for saline environments are used as benchmarks for the characterization of bedrock groundwater. Comparisons of site-specific bedrock groundwater quality data to the

SWQS are provided in Tables 6-26A and 6-27A and in the text sections that follow including separate comparisons to the Acute and Chronic Aquatic criteria and the Human Health criteria.

Class III-B Reclassification

Formal submittals have been made to the NJDEP pursuant to N.J.A.C. 7:9C-1.5(f)4 regarding the reclassification of groundwater within the bedrock and overburden water-bearing zones as Class III-B (Brown and Caldwell, April 2008 and August 2008, respectively). Tremley Point, on which the LCP site is located, is nearly surrounded by estuarine surface water bodies, including the Arthur Kill, Piles Creek, the Rahway River, and various tidal ditches including South Branch Creek. Groundwater beneath the site has been shown to be naturally saline as a result of its proximity and hydraulic connection with these saline surface water bodies. The average concentrations of chloride and TDS in the overburden water-bearing zone exceed the Class III-B criteria by a factor of nearly 150 percent, whereas in the bedrock aquifer they exceed the criteria by a factor of nearly 300 percent (Table 6-24). On this basis, groundwater at the LCP site meets the requirements for Class III-B.

Given its naturally saline condition, groundwater is not utilized as a resource, either by public or private water supply wells within the proposed Class III-B area. Class III-B status has been granted by NJDEP for other nearby sites with similar hydrogeologic conditions as the LCP site (Brown and Caldwell, April 2008 and August 2008). In addition, the Department's Bureau of Water Allocation currently regulates the groundwater at the adjacent GAF site as if it was Class III-B based on the lack of a requirement for a Groundwater Allocation Permit for groundwater withdrawals based on prior demonstration of naturally saline conditions.

Development of Alternative Groundwater Quality Criteria (AGWQC)

Comment [PJT85]: GC#2

The specific groundwater quality criteria in areas designated Class III-B are to be determined on a site-specific basis in accordance with N.J.A.C. 7:9C-1.7(f):

> "The ground water quality criteria for Class III-B areas shall be determined on an area by area basis in response to case by case needs, in the context of applicable regulatory programs. In each case, the criteria shall be no more stringent than necessary to ensure that there will be no:
>
> 1. Impairment of existing uses of ground water;
> 2. Resulting violation of Surface Water Quality Standards;
> 3. Release of pollutants to the ground surface, structures or air in concentrations that pose a threat to human health;
> 4. Violation of constituent standards for downgradient classification areas to which there is a significant potential for migration of ground water pollutants."

Alternative groundwater quality criteria (AGWQC) are proposed herein for the LCP site, as it meets the requirements for Class III-B for both the overburden and bedrock water-bearing zones. The AGWQC have been developed to address the potential groundwater impacts to surface water quality in accordance with N.J.A.C. 7:9C-1.7(f)1, as it has been shown that groundwater from the site discharges to surface water bodies, including South Branch Creek and the Arthur Kill. In addition, AGWQC have been developed to address the risk of direct contact with shallow (overburden) groundwater during potential construction activities in accordance with N.J.A.C. 7:9C-1.7(f)3.

Other requirements for setting AGWQC pursuant to N.J.A.C 7:9C-1.7(f) 1, 3, and 4 are not considered to be applicable to the LCP site, as follows:

- There are no other existing users of groundwater at or in the vicinity of the site.

- There are no occupied areas in which contaminated groundwater from the site could pose a threat to human health via indoor air impacts.[5]
- Continued migration of contaminated groundwater from the site that would impact other downgradient areas cannot occur given the aforementioned discharges to surface water.

The impact to surface water (ISW) and direct exposure AGWQC are developed separately and applied individually to the overburden and bedrock water bearing zones as listed on Table 6-25 and as described in the sections that follow.

Impact to Surface Water (ISW) Groundwater Quality Criteria - "Impact to surface water" (ISW) groundwater quality criteria were derived for the protection of surface water bodies receiving groundwater discharges from the LCP site. Groundwater has been shown to discharge from the overburden water-bearing zone to South Branch Creek and from the bedrock water-bearing zone primarily to the Arthur Kill.

The method utilized to develop the ISW criteria is based on the methodology utilized by Massachusetts for the derivation of "GW-3" groundwater quality standards per the Massachusetts Contingency Plan [310 CMR 40.0000]. Application of this methodology for the ISW criteria development in the absence of applicable methodologies by New Jersey and/or by USEPA is appropriate, as it provides a promulgated procedure that is technically sound. The development of ISW criteria is described below and is presented on Table 6-25. Additional documentation is provided in Appendix L.

Dilution and Attenuation Factor (DAFs) were designated separately for each parameter for which applicable data are available. Two DAFs were estimated for each constituent. Attenuation via subsurface groundwater transport between the source and the surface water body is expressed as the DAF_{GW}. Subsequent dilution once groundwater encounters and discharges to the surface water body is accounted by the DAF_{SW}. The combined DAF (D_{GW} times the D_{SW}) was multiplied by the applicable surface water quality standard or criterion for each parameter to yield an ISW groundwater quality criterion for each constituent.

The criteria used to estimate the DAFs followed the Massachusetts methodology, which was developed to be conservative. The D_{GW} values were designated on the basis of the relative organic carbon partition coefficient (Koc), which is a measure of the tendency for organics to be sorbed onto soil particles (Table 6-25). Specifically, the following D_{GW} values were applied:

- D_{GW} = 2.5 for constituents with a Koc less than 10^3
- D_{GW} = 25 for constituents with a Koc between 10^3 and 10^6
- D_{GW} = 100 for constituents with a Koc greater than 10^6

A default D_{SW} value of 10 was applied for each constituent according to the Massachusetts method. This value can be considered to be very conservative given the fact that dilution by surface water as a function of the groundwater discharge rate may be orders of magnitude greater than 10.

Surface water quality criteria were utilized in the following hierarchy:

1. New Jersey Surface Water Quality Standards (chronic toxicity basis for saline waters) per N.J.A.C 7:9B.
2. National Recommended Water Quality Criteria (NRWQC; USEPA, 2006), Continuous Concentration Criteria (CCC; chronic values) for saltwater

[5] Despite the fact that there are no occupied areas that would be impacted by vapor intrusion, the Human Health Risk Assessment (Appendix Q) has addressed this pathway on a future hypothetical basis.

3. NRWQC Continuous Maximum Concentrations (CMC; acute values) for saltwater.
4. Site-specific benchmarks were developed for benzene, chlorobenzene, and dichlorobenzenes. These overburden groundwater constituents have been shown to potentially discharge to South Branch Creek and were identified at particularly elevated concentrations in wells close to South Branch Creek.

Table 6-25 indicates the source of the benchmarks used in the ISW development.

ISW criteria were not generated for parameters for which surface water criteria are not available. Exceptions to these are the selected aromatic compounds identified above (benzene, chlorobenzene, and dichlorobenzenes) for which site-specific benchmarks were developed. The contaminants that neither USEPA nor New Jersey has developed benchmarks for are, in general, constituents that have not been identified as key aquatic toxins. Selected site-specific benchmarks were developed, however, to ensure that potentially important site-specific contaminants were not omitted from the process. The details of the benchmark development appear in Appendix L.

Direct Contact Groundwater Quality Criteria – AGWQC were developed to address the direct contact exposures resulting from potential subsurface construction work at the LCP site. The direct contact AGWQC are risk-based assuming dermal contact with shallow (overburden) groundwater in an excavation. The exposure variables were obtained from the Human Health Risk Assessment (Appendix P). Construction is assumed to occur continuously over a three-month time period and workers experience dermal contact with groundwater for eight (8) hours per day.

Alternative Groundwater Quality Criteria (AGWQC)

ISW groundwater quality criteria and direct contact groundwater quality criteria have been developed, as described above, for application to the site as AGWQC. These criteria are applied to the water bearing zones at the LCP site as follows:

Overburden AGWQC – The AGWQC applicable to the overburden groundwater will be the lower of the ISW criteria and the direct contact criteria for each chemical constituent (Table 6-25).

Bedrock AGWQC – The AGWQC applicable to the bedrock groundwater will be the ISW criterion for each chemical constituent (Table 6-25).

The AGWQC are applied to the characterization of groundwater quality at the LCP site as is described in the sections that follow.

The complete analytical results of detected constituents in groundwater water are presented in a tabulation in Appendix J. Tables 6-26a and 6-26b presents a summary of descriptive statistics for shallow and deep groundwater results, respectively, collected during the Phase II groundwater sampling event. Exceedances of the AGWQC are summarized in Tables 6-27a and 6-27b.

The characterization of groundwater quality presented in this section, including the groundwater quality maps (Figures 6-18a through 6-23b) and text, concentrates primarily on the Phase II data. The evaluation was done this way due to the more comprehensive nature of the Phase II data, particularly the inclusion of bedrock groundwater quality data, and the fact that the Phase II data are more recent. Observations regarding temporal groundwater quality trends are not provided, or intended, given the fact that the database consists of only two rounds of data spaced five years apart.

6.4.2 Mercury, Other Metals, and Arsenic

Despite the best efforts to minimize suspended solids in groundwater samples using the low-stress (low-flow) sampling technique, it was not possible to completely eliminate solids, particularly in the overburden wells. Given that metals tend to sorb to soil particles, suspended solids in the groundwater sample that originate from the soil in which the wells are screened may cause the over-estimation of

metals concentrations in a unfiltered (total metals) sample because of the fact that soil particles are not mobile in groundwater. An exception, however, is that mobile colloidal-size particles containing metals may be present which generally are mobile in groundwater. For the purpose of this investigation, samples for metals analysis were collected in duplicate: one was field filtered through an in-line 0.45 µm filter, and the other was submitted unfiltered. Notwithstanding the issue of colloids and the official agency position regarding this matter, the filtered (dissolved metals) samples are considered to best represent the mobile concentrations of metals in groundwater.

6.4.2.1 Total Mercury

Total mercury in overburden groundwater samples was detected in 40 percent of the filtered (dissolved) samples and 65 percent of the unfiltered samples (Table 6-26a). ~~However, mercury concentrations in overburden groundwater samples exceeded the overburden AGWQC of 24 µg/L in only five percent of the filtered samples and ten percent of the unfiltered samples.~~ However, mercury concentrations in overburden groundwater samples exceeded the Class IIA groundwater quality standard of 2 µg/L in ten percent of the filtered samples and thirty percent of the unfiltered samples. The highest mercury readings were in well MW-24S located near the "Ditch Bridge Area" along the former alignment of South Branch Creek at 164 µg/L and 233 µg/L in filtered and unfiltered samples, respectively. The only other well in which a dissolved exceedance of the overburden GWQS ~~AGWQC~~ was observed was MW-23S which is located west of mercury cell Building No. 230as depicted on Figure 6-18b. Of particular note, however, is the fact that filtered mercury (Figure 6-18a) was ND in most of the samples located between the production area and South Branch Creek, including each of the wells located east of the railroad tracks.

Mercury concentrations in the bedrock water-bearing zone were substantially lower than in the overburden. In fact, none of the bedrock wells in the vicinity of or downgradient of the LCP production area contained detectable levels of mercury. The only mercury in the bedrock was observed in the four upgradient wells (under non-pumping conditions including MW-16D, MW-17D, MW-18D, and MW-20D (Figures 6-18c and 6-18d). The highest concentrations were observed in MW-18D at 10.9 and 11.1 µg/L in filtered and unfiltered samples. ~~, respectively none of which exceeded the bedrock AGWQC of 24 µg/L.~~ Exceedances of the Saline Human Health SWQS of 0.051 µg/L were noted for each well with mercury detections. Exceedances of the ecological CCC and CMC values were noted for wells MW-17D, MW-18D, and MW-20D. Of note is the fact that the filtered and unfiltered sample pairs from bedrock wells were very similar to one another, which is not surprising given the greater ease of collecting low-turbidity samples by the low-stress method in the bedrock relative to that in the overburden wells.

Mercury concentrations in overburden groundwater are relatively low considering the elevated levels of mercury that are present in the soils. Mercury in groundwater is generally restricted to areas of the site in which very high levels of mercury are observed in the soils. These data provide additional confirmation that the mercury in the LCP site soil is present in primarily insoluble forms. Detectable mercury in groundwater is relatively immobile and does not create groundwater plumes that extend laterally from the likely source areas.

Mercury in groundwater was largely undetected around the perimeter of the closed RCRA unit (former brine storage lagoon), demonstrating that that unit is not a source of mercury in groundwater. Exceptions include two low-level detections in unfiltered samples at levels that do not exceed the overburden NJGWQS of 24 µg/L or the NJGWQS of 2 µg/L.

~~The only bedrock wells that contain detectable levels of mercury are located northwest of the LCP production area. These data reveal that the mercury in the bedrock may have an off-site source with a higher mercury solubility than the mercury that is generally found on the remainder of LCP site. The concept of contaminant transport within the bedrock water bearing zone is complicated by the alteration of groundwater flow that occurs as a result of the bedrock groundwater extraction system on the~~

Comment [PJT86]: GC#2

Comment [PJT87]: GC#2

Comment [PJT88]: GC#2

Comment [PJT89]: GC#3 – Revised Fig 6-18b

Comment [PJT90]: GC#3 – Revised Fig 6-18a

Comment [PJT91]: GC#3 – Revised Figs 6-18c – 6-18d

Comment [PJT92]: GC#2

Comment [PJT93]: SC#15

~~adjacent GAF site. The GAF groundwater extraction system is observed to induce bedrock groundwater flow from the GAF site (Figures 5-12 and 5-13) onto the western portion of the LCP site. The bedrock groundwater at the GAF site is demonstrated to contain elevated levels of mercury. Therefore, soluble mercury in the northwest LCP bedrock wells (MW-17D, MW-18D, and MW-20D) occurs as a result of the GAF groundwater extraction system. The mercury observed in the bedrock wells will be re-captured and subsequently treated by the GAF remediation system.~~

The only bedrock wells that contain detectable levels of dissolved mercury are located northwest of the LCP production area (MW-17D, MW-18D, and MW-20D) and contain mercury concentrations ranging up to10.9 µg/L. Under pumping conditions, groundwater has been demonstrated to originate from the adjacent GAF site, sweeping through the western portion of the LCP site in which these wells are located, and then back to the GAF site to be captured by extraction well DEW-4A (Section 5.2.3.3). Relatively high dissolved mercury concentrations have been observed in nearby wells on the adjacent GAF site, which are the likely source of the mercury in the three LCP bedrock wells. These data demonstrate that the only dissolved mercury detected in bedrock at the LCP site originates from the GAF site.

Evidence of the mercury mobility in bedrock groundwater is provided by the apparent relative mercury solubility differences between the LCP and GAF sites. The mercury sources in soil at the LCP site have been demonstrated to consist primarily of insoluble forms (Section 6.1.1), which is consistent with the generally low levels of dissolved mercury detected in overburden groundwater at the LCP site. Contrasted with this is that dissolved mercury at the GAF site has been observed at concentrations that are orders of magnitude higher than at the LCP site, ranging up to 2,520 µg/L, suggesting the presence of much more soluble forms of mercury at the GAF site. Furthermore, none of the LCP bedrock wells containing detectable mercury were located in overburden groundwater. Only bedrock wells in the northwest portion of the Site had detectable mercury. In summary, the soluble mercury from the GAF site is the likely source of mercury in the LCP bedrock wells and this mercury is being captured by the GAF groundwater extraction system.

6.4.2.2 Methyl Mercury

Methyl mercury was analyzed in six selected wells, three (3) of which were in the overburden and three (3) in the bedrock. Table 6-28 presents the total mercury results (filtered and unfiltered) in comparison to the total methyl mercury results in each respective sample.

Comment [PJT94]: GC#3 – Revised Table 6-28

The methyl mercury results in the tested overburden groundwater samples ranged from 0.635 µg/L to 168 µg/L, corresponding to 0.32 percent to 102 percent[6] of the total mercury (Figure 6-19a). The highest methyl mercury concentration was detected in monitoring well MW-24S, in which a very high proportion of the total mercury was in the methyl form. This result is in contrast to methyl mercury results in other site groundwater, soil, and sediment samples in which methyl mercury made up a very minor proportion of the total mercury, generally far less than 1 percent. As stated previously, MW-24S is screened in the Ditch Bridge Area along the former alignment of South Branch Creek in which methylation could have occurred in sediments prior to filling of this area after 1972 (Section 2.6.1).

In the tested bedrock groundwater samples, methyl mercury was analyzed in three wells, with results ranging from 0.0192 µg/L to 0.188 µg/L (Figure 6-19b). The proportion of methyl mercury ranged from 0.01 percent to 0.09 percent (Table 6-28), which is similar to methyl mercury proportions in other media at the site.

[6] The calculated percentage of methyl mercury greater than 100 percent of total mercury reflects the variability in the analysis, which was well within acceptable QC criteria established by USEPA.

6.4.2.3 Arsenic

Arsenic in overburden wells was detected in 70 percent of the unfiltered and filtered samples. Overburden groundwater arsenic concentrations ranged up to 588 µg/L (MW-12S) for dissolved (filtered) samples and 275 µg/L (MW-26S) for unfiltered samples. Each detection of arsenic was above the GWQS of 3 µg/L. ~~., none of which exceeded the overburden AGWQC of 800 µg/L.~~ The distribution of arsenic in overburden groundwater is depicted on Figures 6-20a and 6-20b. In general, total and dissolved sample concentrations were comparable, indicating that arsenic occurs in groundwater in a soluble form. Anomalous results are observed in well MW-12S in which the filtered result was substantially higher at 588 µg/L compared to 192 µg/L in the corresponding unfiltered sample.

Arsenic in overburden groundwater was widely distributed across the site and appears to be spatially unrelated to ~~either the arsenic distribution in the anthropogenic soils or~~ the LCP manufacturing area. In fact some of the lower arsenic concentrations in overburden groundwater were observed in the area immediately surrounding the LCP production buildings. In addition, arsenic was undetected in the wells located downgradient of the closed RCRA unit further supporting that arsenic in groundwater is unrelated to LCP operations. Due to the distributed pattern of concentrations in the overburden groundwater, the source of arsenic is most likely from the anthropogenic fill. ~~Regardless, the source of arsenic in groundwater is from arsenic in the anthropogenic fill. In fact some of the lower arsenic concentrations in overburden groundwater were observed in the area immediately surrounding the LCP production buildings. In addition, arsenic was undetected in the wells located downgradient of the closed RCRA unit.~~

Arsenic in bedrock wells was detected in 30 percent of the unfiltered and filtered samples and at concentrations that are substantially lower than in the overburden groundwater. Bedrock groundwater arsenic concentrations ranged to 27.7 µg/L for dissolved samples and 25.2 µg/L for unfiltered samples collected from MW-11D. ~~, none of which exceeded the bedrock AGWQC of 900 µg/L.~~ Exceedances of the Saline Human Health SWQC of 0.061 µg/L were noted in wells MW-11D, MW-16D, MW-23D, and MW-25D. The distribution of arsenic in bedrock groundwater is depicted on Figures 6-20c and 6-20d.

6.4.2.4 Other Metals and Inorganics

Cadmium in overburden groundwater was detected in just 5 percent and 15 percent, respectively of the filtered and unfiltered overburden groundwater samples. ~~None~~ Each of these detections exceeded the overburden ~~AGWQC of 220 µg/L~~ GWQS of 4 µg/L, in which the maximum concentrations ranged up to 10.5 and 22.9 µg/L in filtered and unfiltered samples, respectively. Concentrations in the filtered and unfiltered samples were generally comparable, with the exception of MW-7S, which showed a concentration of 22.9 µg/L in the unfiltered sample, with no cadmium detected in the filtered sample. ~~It is likely that the presence of cadmium in overburden groundwater is related to the presence of anthropogenic fill.~~ Cadmium was not detected in bedrock groundwater.

Barium in overburden groundwater was detected in just 5 percent of both the filtered and unfiltered overburden groundwater samples. ~~None~~ One well, MW-21S, revealed exceedances the overburden ~~AGWQC of 220 µg/L~~ GWQS of 6000 µg/L, in which the maximum concentrations were 15,300 and 14,200 µg/L in filtered and unfiltered samples, respectively. Barium was detected in 30 percent of both the filtered and unfiltered bedrock groundwater samples, with a maxium detection of 288 µg/L. There are no saline SWQSs for Barium for comparison to bedrock groundwater quality data.

Chromium was detected in 25 percent and 30 percent, respectively, of the filtered and unfiltered overburden and bedrock groundwater samples. ~~None~~ One well, MW-18S, revealed exceedances the overburden ~~AGWQC of 220 µg/L~~ GWQS of 70 µg/L, in which the concentration was 211 and 233 µg/L in filtered and unfiltered samples, respectively. Chromium was detected in 1 unfiltered bedrock

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Comment [PJT99]: GC#2

Comment [PJT100]: GC#2

Comment [PJT101]: GC#2

Comment [PJT102]: GC#2

groundwater sample, with at 10.3 µg/L. The result did not exceed the Saline Human Health SWQC of 750 µg/L.

Cyanide in overburden groundwater was detected in 16 percent of groundwater samples. There were three detections of cyanide ranging from 20 to 77 µg/L, each exceeding the overburden GWQS of 0.1 µg/L. The wells with cyanide detectiond included MW-17S, MW-12S, and MW-18S. Cyanide in two unfiltered bedrock groundwater samples at concentrations of 11 and 12 µg/L. Each of these samples exceeded the USEPA Saline Ecological Criteria Continuous Concentration (CCC) and the USEPA Saltwater Criteria Maximum Concentration (CMC) criteria of 1.0 µg/L.

It is likely that the presence of cadmium, chromium, and cyanide in overburden groundwater are related to the presence of anthropogenic fill.

Lead was detected in 5 percent and 20 percent, respectively, of the filtered and unfiltered overburden groundwater samples and in 80 percent of the filtered and unfiltered bedrock groundwater samples. Dissolved and total concentrations were generally comparable. Two of the unfiltered overburden lead results exceeded the overburden ~~AGWQC of 600 µg/L~~ GWQS of 5 µg/L (MW-23S and MW-18S) No exceedances of of the lead GWQS were found in dissolved samples from the overburden. Exceedances of the CCC criterion of 8.1 µg/L were noted in 7 dissolved samples and 5 unfiltered samples. ~~or the bedrock AGWQC of 600 µg/L.~~

Comment [PJT103]: GC#2

Iron was detected in 90 percent and 100 percent, respectively, of the filtered and unfiltered overburden and bedrock groundwater samples. 85 percent of the unfiltered and filtered samples in the overburden exceeded the GWQS of 300 µg/L. There are no saline SWQC for Iron. ~~Iron exceeded the overburden AGWQC of 25,000 µg/L in three overburden and one bedrock groundwater well for both total and filtered samples. In addition, one sample exceeded the 2,200µg/L overburden AGWQC for aluminum.~~

Manganese was detected in 95 percent of both the filtered and unfiltered overburden groundwater samples and in 100 percent of both the filtered and unfiltered bedrock groundwater samples. Dissolved and total concentrations were generally comparable. 85 percent and 90 percent, respectively, of the unfiltered and dissolved overburden manganese results exceeded the GWQS of 50 µg/L. 90 percent and 100 percent, respectively, of the unfiltered and dissolved bedrock results exceeded the Saline Human Health SWQC of 0.061 µg/L.

Lead, iron, and manganese are major constituent in natural soils and rock; hence elevated groundwater levels are not unexpected.

6.4.3 Organics

Several volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) were observed in both overburden and bedrock groundwater at the site. Aside from known and suspected storage of petroleum and heating oil in the vicinity of the Linde Hydrogen Plant, organic compounds are not known to have been used in production at the LCP site. The highest VOC/SVOC detections are attributed to off-site sources including the adjacent NOPCO site and the former GAF site. However, many of these same compounds are also found in the soils at the site and wide distribution within the overburden groundwater may be attributed, in part, to dissolution from the anthropogenic fill. The bulk petroleum product terminal facilities have been located in close proximity to the LCP site for more than 50 years and have likely contributed to regional contamination by VOCs and other fuel-related compounds.

Comment [PJT104]: SC#36

Benzene, various chlorobenzene compounds, and 4-chloroanaline were observed in the overburden groundwater at concentrations that exceed the respective overburden GWQS.~~AGWQCs~~. The specific exceedances are listed on Table 6-27a. The spatial distributions of benzene and chlorobenzene in overburden groundwater are depicted on Figures 6-22a and 6-23a, respectively. The exceedances of

Comment [PJT105]: GC#2

the overburden GWQS.~~AGWQCs~~ were observed in ~~only four~~ thirteen overburden wells. ~~These include wells MW-6S, MW-11S, MW-21S, and MW-24S.~~

Substantially elevated levels of benzene, chlorobenzene and 1,2-dichlorobenzene that exceed the overburden GWQS.~~AGWQCs~~ were observed in wells MW-6S, MW-21S, and other overburden wells to the northwest of those wells. ~~Likewise, an exceedance of chlorobenzene was observed in well MW-11S.~~ These exceedances likely result from residual subsurface materials from the former NOPCO site which was located immediately adjacent to wells MW-6S and MW-~~11~~21S. Given these observations and the fact that chlorobenzene is not related to chlor-alkali facilities, their presence in ~~well MW-6S~~ these overburden wells is likely due to the former NOPCO site. VOCs in well MW-6S present a potential risk to surface water quality given its proximity to South Branch Creek.

Well MW-24S, located in the former "Ditch Bridge" area was impacted by exceedances of the overburden GWQS.~~AGWQCs~~ for benzene, chlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, pentachlorophenol, hexachlorobenzene, methylene chloride, and tetrachloroethene.~~-~~The presence of these compounds likely results from historic wastewater transport across the LCP site from the adjacent GAF site~~.and several PDCFs~~. ~~An exceedance of the AGWQCs for chlorobenzene was also detected in well MW-11S. Each of these wells is located along the southerly loop alignment of the former wastewater ditch that existed from approximately 1947 to 1966 (see Section 2.6.1) and conveyed wastewater from the former GAF site. While these constituents exceed the AGWQC developed on the basis of potential impacts to surface water, it is unlikely that they are currently impacting surface water quality given the fact that they are not distributed as laterally extensive plumes that extend to South Branch Creek.~~

~~Exceedances of the overburden AGWQC of 1,700 µg/L for 4-chloroanaline were observed in four overburden wells. 4-chloroanaline was not used at the LCP site. However, the presence of 4-chloroanaline likely results from historic wastewater transport across the LCP site from the adjacent GAF site.~~

Several VOCs/SVOCs including benzene, toluene, and 1,2,4-trichlorobenzene ~~chlorobenzene, and 1,2-dichlorobenzene,~~ exceeding the Saline Human Health SWQC, were observed in the three bedrock wells located in the northwestern portion of the site, upgradient of the manufacturing area, including wells MW-17D, MW-18D, and MW-20D, exceeding the Saline . Much lower levels of these compounds were also detected in several other wells around the site. The specific bedrock exceedances are listed on Table 6-27b. The aerial distributions of benzene and chlorobenzene in bedrock groundwater are depicted on Figures 6-22b and 6-23b, respectively. ~~Three of the chlorobenzene or 1,2-dichlorobenzene detections exceeded their respective AGWQC 620 µg/L and 500 µg/L.~~

Benzene and chlorobenzenes were not used in production at the LCP site but are documented to be present in groundwater at the adjacent GAF site. The northwestern bedrock wells in which benzene and chlorobenzenes were detected are within the zone in which the GAF groundwater extraction system has been shown to induce bedrock groundwater flow from the neighboring GAF site. Accordingly, benzene and chlorobenzenes in bedrock is present as a result of the GAF site in the same manner as is mercury. The benzene and chlorobenzene in the northwestern bedrock wells is captured and subsequently treated by the GAF remediation system.

One sample groundwater samples from each zone was analyzed for PCDD/PCDF. Very low levels of both PCDDs and PCDFs were detected in each sample with TEQs of 0.181 ng/L (0.000181 µg/L) and 0.00882 ng/L (0.00000822 µg/L in the overburden and bedrock, respectively. Given the extremely low solubilities of PCDDs and PCDFs in water, these detections are likely associated with solids in the sample rather than representing dissolved phase constituents. The turbidity of the overburden sample was 16.2 NTU while the bedrock sample was 271 NTU. The overburden TEQ is dominated by the PCDFs in a similar pattern as the fill soils in this unfiltered that further supports site soil impacts on this

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Comment [PJT116]: SC#37

groundwater sample. The exceedingly low TEQ was in the bedrock groundwater sample ~~is likely~~ may be due to a very small level of cross-contamination that may have occurred either during well installation or during sampling that is observable due to low detection limits for PCDD/PCDF analysis.

No free phase liquids were observed in the groundwater column in either overburden or bedrock monitoring wells.

6.5 Surface Water

Surface water samples were collected from five locations in South Branch Creek and two locations in the Arthur Kill (see Figures 3-1 and 3-2). As discussed in Section 3.3.4, these stations correspond to the transects along which the sediment samples were collected. Additional surface water samples were collected from the Off-Site Ditches from two locations in each ditch.

The complete analytical results of detected constituents in surface water are presented in Appendix J A total of 13 TCL and 13 TAL chemical constituents were detected in the unfiltered surface water samples collected from South Branch Creek. In unfiltered surface water samples from the Arthur Kill, 1 TCL and 9 TAL chemical constituents were detected. There were 11 TCL and 15 TCL chemical constituents found in surface water samples from the Northern Off-Site ditch, while 8 TCL and 12 TAL constituents were detected in the Southern Off-Site Ditch. Table 6-30 presents a summary of descriptive statistics for surface water chemicals collected in South Branch Creek and the Arthur Kill and the Off-Site Ditches.

Both chronic and acute toxicity criteria are available for surface water for various constituents including mercury. The chronic value is referred to as Criteria Continuous Concentration (CCC), which is an estimate of the highest contaminant concentration to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. The acute value, Criterion Maximum Concentration (CMC), is an estimate of the highest contaminant concentration to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. Applicable water quality criteria have not been developed for any of the detected chemicals on an unfiltered basis. USEPA National Recommended Water Quality Criteria (NRWQC) for saltwater exist for dissolved arsenic, cadmium, copper, lead, mercury, selenium and zinc; however, filtered inorganics were not analyzed during the Phase I and II investigation with the exception of the tidal evaluation for mercury, described below and the Off-Site Ditch investigation. In addition, due to the tidal influences and the inherently mobile nature of surface water, the surface water data provide limited information on nature and extent of contamination in the water bodies compared with sediment.

The horizontal and vertical delineation of site-related constituents for surface water is adequate to perform the analysis and selection of remedial alternatives as part of the Feasibility Study (FS). Additional delineation of surface water may be performed, as necessary, as part of a Pre-Design Investigation (PDI).

6.5.1 Mercury

The unfiltered surface water data indicate higher overall inorganic concentrations in South Branch Creek and the Northern Off-Site than in the Arthur Kill. This observation is likely related to the greater presence of suspended particulates in stations closer to the site.

The maximum mercury concentration observed in South Branch Creek in Phase II was at Transect A (5.8 µg/L). ~~This concentrations is approximately 10,000 times lower than the total general mercury sediment concentration (averaging in the 100s of mg/kg) in the corresponding area.~~ In Phase II, surface water mercury concentrations declined approaching the Arthur Kill, with the lowest concentrations observed at Transects F and G, and concentrations in South Branch Creek approximately 10-fold higher than in the Arthur Kill. (Appendix J). However, in Phase I, the maximum observed overall mercury concentration (18.1 µg/L) was at SW-5, in the general vicinity of Transect D. The concentration of

Comment [PJT117]: SC#37

Comment [PJT118]: Ditch Report

Comment [PJT119]: Ditch Report

Comment [PJT120]: Ditch Report

Comment [PJT121]: Ditch Report

Comment [PJT122]: Ditch Report

Comment [PJT123]: GC#3

Comment [PJT124]: Ditch Report

Comment [PJT125]: SC#38

unfiltered metals found in surface water is dependent on when in the tidal cycle the sample is collected (as discussed further below). Therefore, it is not possible to directly compare Phase I and Phase II surface water data.

To address the influence of tidal conditions, an additional separate sampling effort was performed to determine whether mercury from South Branch Creek is being transported to the Arthur Kill in either the dissolved or particle-bound phase. Particle-bound mercury, dissolved mercury, and suspended solids were sampled during two-hour intervals throughout an entire tidal cycle in February 2007. The samples were collected from the petroleum terminal bridge spanning South Branch Creek between Transects C and D. The data are summarized on Figure 6-24. Based on filtered surface water results, dissolved mercury was undetected in each of the samples. Therefore, mercury detected in surface water is associated with the suspended solid phase. Mercury was observed in each of the unfiltered surface water samples collected from South Branch Creek at concentrations ranging up to 5.8 µg/L, with a mean concentration of 3.2 µg/L.

Mercury was detected in both unfiltered and dissolved samples in the Northern Off-Site Ditch with a maximum concentration of 13.1 µg/L for unfiltered samples and 0.0173 µg/L for dissolved samples. The difference in mercury concentrations between total and dissolved samples indicated the mercury found in the Northern Off-Site Ditch is primarily associated with suspended particles.

Comment [PJT126]: Ditch Report

Mercury was also detected in both the unfiltered and dissolved samples in the Southern Off-Site Ditch, however at much lower concentrations. A maximum concentration of 0.022 µg/L for unfiltered samples and 0.001 µg/L for dissolved samples was found in samples from the Southern Off-Site Ditch.

The CCC and CMC values for dissolved mercury are 0.94 and 1.8 µg/L, respectively. The highest unfiltered mercury concentrations in South Branch Creek were measured during ebb tide and the flood when water velocity is highest, which creates the maximum potential for mercury-containing solids to be suspended. The lowest mercury concentrations were measured during periods of high and low slack tide, when water velocity is low. Figure 6-24 shows that the values for total suspended solids and turbidity follow the same tidal pattern. The pattern of mercury presence in surface water is clearly dependent on the tidal condition. The CCC and CMC values for mercury were not exceeded in dissolved samples from either the Northern or Southern Off-Site Ditches.

Comment [PJT127]: SC#39 – Revised Table 6-30

Comment [PJT128]: Ditch Report

6.5.1.1 Methyl Mercury

Methyl mercury was also detected in each of the five unfiltered surface water samples collected at South Branch Creek in the Phase II RI, with a maximum concentration of 19.5 ng/L (0.0195 µg/L). In the two unfiltered surface water samples collected from the Arthur Kill, the maximum concentration of methyl mercury was 0.738 ng/L (Table 6-31). No Saltwater CCC and CMC values have been established for methyl mercury. The percentage methyl mercury of the total mercury concentration was low in all of those samples, with a maximum of 0.34 percent in South Branch Creek, and 0.31 percent in the Arthur Kill surface water samples.

Methyl mercury was also detected in the surface water collected during the regional study within Old Place Creek, where the maximum concentration was 0.091 ng/L (0.00091 µg/L; Appendix N Table N-2). This concentration is more than two order of magnitude below the highest level observed in the surface water in South Branch Creek, which would be expected based on the lower overall surface water mercury concentrations. However, the percentage methyl mercury of the total mercury concentration was 0.07 percent in the samples from the regional study, also lower than in either South Branch Creek or the Arthur Kill. These results indicate a lower rate of methylation.

As discussed further in Section 7.1.6, various factors affect the observed methylmercury presence in each medium. However, the net methylation rate (which accounts for both formation and removal mechanisms) in Old Place Creek surface water is, empirically, several times higher than that in South

Comment [PJT129]: SC#40

Branch Creek. In South Branch Creek and the Arthur Kill, methyl mercury represented between 0.05 and 0.16 percent of total mercury; in Old Place Creek, the percentage of mercury in the methylated form ranged from 0.35 to 0.51 percent. A similar pattern is observed in sediment, with South Branch Creek/Arthur Kill samples typically exhibiting less than 0.05 percent methylmercury, while Old Place Creek samples (except W 1 and W 2) contained 0.1 to 0.39 percent methylmercury. These data do not necessarily reflect the initial rate of methylation, but do suggest that overall the South Branch Creek system is producing a lower net rate of mercury methylation.

6.5.2 Other Metals and Arsenic

Of the 22 elements analyzed other than mercury, 12 metals and arsenic were detected in the surface water samples of South Branch Creek, eight in the Arthur Kill, 15 in the Northern Off-Site Ditch and 11 in the Southern Off-Site Ditch (Table 6-30, Appendix J). The frequency of detection for the South Branch Creek samples ranged from 20 to 100 percent. In the Arthur Kill samples, the detection frequency ranged from 50 to 100 percent. In Phase I, arsenic was observed between 59 µg/L and 114 µg/L in the near-facility portions of South Branch Creek (SW-1 through -3), declining to the 40 µg/L range further toward the Arthur Kill (SW-4 and -5) and to ND by the Arthur Kill (SW-6). Several metals (barium, lead, cadmium, iron, and zinc) showed the highest concentrations in the mid-South Branch Creek areas (SW-3 through SW-5) and lower concentrations closer to the former facility and in the Arthur Kill. In Phase II, however, the highest arsenic and metal concentrations were typically in the Transect A and B stations. As indicated above, the tidal influence prevents direct comparison of the results from the two sampling events, and concentrations are related to the presence of suspended material.

Comment [PJT130]: Ditch Report

Various inorganic constituents were found in unfiltered samples exceeding the Saltwater CCCs and CMCs in the Off-Site Ditches, including arsenic, cadmium, copper, lead, nickel, and zinc, however only arsenic was found to exceed the criteria in dissolved samples. Dissolved arsenic was detected in the Northern Off-Site Ditch at concentrations up to 152 µg/L, while the highest concentration found in the Southern Off-Site Ditch was 42 µg/L. Additionally manganese was found to exceed saltwater Human Health criteria in dissolved samples in both ditches, with a maximum concentration of 624 µg/L in the Northern Off-Site Ditch and 598 µg/L in the Southern Off-Site Ditch.

Comment [PJT131]: Ditch Report

6.5.3 Organics

Traces of several PAHs (fluoranthene, fluorene, naphthalene, and phenanthrene, all less than 1 µg/L) were reported in the Phase II surface water samples at Transect A; a fraction of a µg/L of naphthalene was also reported in the Arthur Kill sample at Transect G. PAHs may be present as part of the suspended solids due to erosion of fill material.

Pesticide and PCB compounds, PCNs, and hexachlorobenzene were not detected in surface water.

Benzene and chlorinated benzenes (1,2- and 1,4-dichorobenzene and 1,2,4-trichlorobenzene) were detected in several surface water samples collected in South Branch Creek in both Phase I and II. No aquatic life-basis CCC or CMC values are available for these compounds. However, based on a literature review, aquatic life protection benchmarks were developed for benzene, chlorobenzene, 1,2- and 1,4-dichlorobenzene (Table 6-25). While occurrence was scattered, most of the higher reported concentrations were clustered in the Transects A, C, and D areas. These constituents were detected in groundwater and soil throughout the site. They were also present at substantially elevated concentrations in MW-6, a shallow well about 50 feet from South Branch Creek from which groundwater would be expected to discharge to the creek somewhere between Transects B and C. The chlorinated benzenes in surface water may be due at least in part to shallow groundwater infiltration. However, their widespread occurrence in surface water and sediments (see below) suggests a migration mechanism similar to that of other adsorbed site contaminants including historic wastewater and storm water discharge from the LCP and GAF sites..

Scattered detections of other VOCs (tert-butyl methyl ether and Freons) were reported in South Branch Creek surface water samples. The frequency of detection ranged from 20 to 40 percent. These constituents were not present in shallow groundwater near the stream and do not appear to be related to the site. VOCs were not detected in the surface water samples collected from the Arthur Kill.

6.6 Sediment

Phase II sediment samples were collected along five (5) transects located in South Branch Creek and two transects in the Arthur Kill near the mouth of South Branch Creek. Nine additional 0-0.5-foot samples were collected in the Phase I RI. The samples were collected following methods described in Section 3.3.5.

Phase II sediment samples were sampled to "human refusal", which occurred at depths ranging from 0.5 to 2.5 feet. Sample refusal, the depth at which the manually operated sampler could no longer penetrate, is assumed to correspond to the bottom of the sediment which is believed to be considerably softer than the underlying soils.

As described in Section 3, an extensive list of chemical constituents was analyzed in sediment as described in Section 3.7. The complete analytical results of detected constituents in sediment are presented in Appendix J. Of these, 23 TAL and 63 TCL analytes were detected in South Branch Creek (Transects A through E), and 20 TAL and 45 TCL analytes were detected in the Arthur Kill (Transects F and G). Table 6-32 presents a summary of descriptive statistics for the sediment samples for South Branch Creek and the Arthur Kill. Figures 6-25a through 6-27d show the spatial distribution of mercury, arsenic, and the total PCBs, Aroclor 1254 and Aroclor 1260, in the sediments from South Branch Creek and the Arthur Kill.

A regional study was performed in Old Place Creek in Staten Island, New York, a tributary of the Arthur Kill following the same methods and procedures as used during the LCP Phase II RI in which 86 analytes were detected. A summary of descriptive statistics for sediment samples collected during the regional study can be found in Appendix N, Table N-4.

There are no promulgated regulatory standards for sediment quality. However, the ER-L and ER-M screening values (Long, *et al.*, 1995) are used to provide a context for assessing the sediment data. These screening levels were selected from among several sets of frequently cited benchmarks because they are preferred by the NJDEP (NJDEP, 1998). The ER-Ls and ER-Ms represent the 10th and 50th percentile concentrations, respectively, associated with observed biological effects from systems with multiple contaminants. Correlation between effects and concentrations for many constituents, including mercury, was described by the Long, *et al.* (1995) as "weak." The ER-Ls are used as a threshold below which biological effects are not expected. The ER-Ms are indicators of when effects might be expected. The ER-Ms do not indicate biological hazard, only that additional risk evaluation may be warranted. Tables 6-33a and 6-33b list the ER-L and ER-M values for various constituents, along with exceedances of these screening values for South Branch Creek.

The ER-L value was exceeded for 23 constituents in at least one sample from South Branch Creek, and for 22 in the Arthur Kill. Twenty-two chemicals exceeded respective ER-Ms in South Branch Creek, 17 in the Arthur Kill. This pattern suggests a comparable level of criterion exceedance in both sampled areas.

In the descriptive text that follows, the South Branch Creek samples refer to those collected along Transects A through E, and the Arthur Kill samples refer to Transect F and G which are near the mouth of South Branch Creek. The transect locations are depicted on Figures 3-1 and 3-2, as well as contaminant-specific figures discussed below.

The horizontal and vertical delineation of site-related constituents for sediment is adequate to perform the analysis and selection of remedial alternatives as part of the Feasibility Study (FS). Additional delineation of sediment may be performed, as necessary, as part of a Pre-Design Investigation (PDI).

Comment [PJT132]: GC#3

6.6.1 Mercury

Total Mercury

Total mercury was detected in 98 percent of the sediment samples in South Branch Creek, and in 100 percent of the sediment samples in the Arthur Kill (Table 6-32, Figure 6-25a, through 6-25d), and 100 percent of the sediment samples from both Off-Site Ditches (Figure6-25e). . The ER-L and ER-M concentrations for mercury are 0.15 and 0.71 mg/kg, respectively. Mercury concentrations exceeded both the ER-L and ER-M threshold in 48 of the 49 South Branch Creek sediment samples and also in all six of the sediment samples from the Arthur Kill. Although mercury was found in both areas, concentrations of mercury were higher in South Branch Creek than in the Arthur Kill. Mercury concentrations exceeded the ER-L threshold in each of the Off-Site Ditch samples. The ER-M threshold was exceeded in each of the samples from the Northern Off-Site Ditch, and 67% of the Southern Off-Site Ditch. The overall concentrations of mercury in the Northern Off-Site Ditch were elevated, averaging 90.2 mg/kg, although they were generally lower than those found in South Branch Creek. Concentrations of mercury in the Southern Off-Site Ditch were significantly lower, averaging 1.29 mg/kg.

Comment [PJT133]: Ditch Report

Comment [PJT134]: Ditch Report

As indicated on Figures 6-25a, there is a pattern of generally declining mercury concentrations in surficial sediment along South Branch toward the Arthur Kill. Maximum mercury concentrations (in the 300-400 mg/kg range) were reported in stations SED-A-1, SED-A-2, and SED-2, each of which was located at the headwaters of South Branch Creek. In the Transect B/SED-3 area, approximately 350 feet closer to the Arthur Kill, concentrations are substantially lower (all below 200 mg/kg). Slight increases are observed in the SED-C area, which is likely related to the depositional nature of this “back-bay” area and possibly to the presence of additional drainage inputs from the large concrete outfall that is a historic remnant of the City of Linden trunk sewer line. Further toward the Arthur Kill, concentrations continue to decline, with concentrations between 24.5 and 128 mg/kg observed in the first Arthur Kill transect (Transect F). At Transect G, furthest out in the Arthur Kill, mercury ranged from 0.86 to 12.5 mg/kg. These concentrations are similar to those observed throughout the Arthur Kill in both published agency databases and in samples collected in Old Place Creek (Appendix N). Extensive regional information published by various agencies (Figure 2-26) indicates that mercury in the Arthur Kill is generally in the single digit mg/kg range. Samples collected form Old Place Creek to supplement the regional information revealed an average mercury concentration of around 7 mg/kg (Table N-4). Thus the concentrations of mercury in Transect G, which average 5.5 mg/kg, indicates that mercury attenuates to background in the area of the Arthur Kill just beyond the mouth of South Branch Creek.

Similar attenuation is observed for the deeper sediments (Figures 6-25b through 6-25d):, there is more of a distinct increase in mercury accumulation in the Transect C and D areas relative to more near-facility locations than is observed in the 0-0.5-depth interval, but the concentrations in sample SED-6 at Transect F (8.7 mg/kg at 0.5-1.0 feet and 4.8 mg/kg at 1.0-1.5 feet) are well within the range of background.

The pattern of mercury concentrations in surficial sediment in the Northern Off-Site Ditch do not show a decreasing gradient from upstream to downstream, however that is to be expected due to the parallel run of the ditch adjacent to former operations areas of the LCP Site. The concentrations of mercury in the Southern Off-Site Ditch are lower than those found in the Arthur Kill during the Phase II RI. The mercury results of the two off-site ditches indicates the Northern Off-Site Ditch has been impacted by runoff with contaminated sediment from the LCP Site, while the Southern Off-Site Ditch has not.

Comment [PJT135]: Ditch Report

Table 6-34 and Figure 6-28 present the mercury sediment results in South Branch Creek by depth for each station (along with selected other elements). For clarity of display, the graphical patterns are presented separately for each transect. The pattern of mercury presence by depth is highly variable. In certain locations (such as SED-5 and SED-6) there is a marked gradient with depth such that mercury declines to background levels by the 1.0 to 1.5-foot depth interval. At other stations, there is no apparent decrease with depth, and the location where the deepest sediment was available for collection (SED-D-2) showed essentially no change in concentration down to 2.5 feet. Several stations (notably SED-3) exhibited a maximum observed concentration in the second shallowest depth interval (0.5-1.0 feet). Overall, there appears to be no correlation between the location along the channel and the vertical mercury gradients. This heterogeneity probably reflects the tidal flushing and related processes of deposition and re-suspension that vary by location and have resulted in variable degrees of sediment mixing over time.

Sequential Extraction

Seven samples from three transects were submitted for analysis by a selective sequential extraction method after Bloom, *et al.*, (2003). This five-step sequence of extractions groups mercury compounds into "biogeochemically" distinct categories. These data are presented in Table 6-35.

The majority of the mercury present was associated with fraction F4. F4 comprised between 65 and 88 percent of total mercury, and the proportion was not related to the total mercury detected or the location within the areas evaluated (Transects A through C). The next most common forms of mercury present extracted with the F5 fraction, indicating highly insoluble mercury sulfide. Higher total mercury concentrations appear to be associated with a higher proportion of F5 and a lower proportion of acid soluble (F2) but the correlations are weak and there are an insufficient number of data points to draw any firmer conclusions. There is essentially no soluble mercury in sediments. These results were very similar to the on-site surficial soils in which elemental mercury and mercury sulfides were predominant.

The developers of the sequential extraction procedure indicate in their paper (Bloom, *et al.*, 2003) that the presence of methyl mercury cannot always be definitively linked with one of the sequential extraction fractions, as mercury methylation is variable based on specific conditions (See Section 7 for additional discussion of factors affecting methylation). However, case studies indicate that the methyl fraction may be associated with F3 (organo-chelated forms). The percentage of mercury present in the F3 fraction is South Branch Creek sediments ranged from 0.16 to 4.8 percent of total mercury. Methyl mercury analyses were not performed on these specific samples; however, based on the extremely low presence of methyl mercury as a percentage of total mercury (Table 6-36), it is certainly feasible that the very low concentrations of methyl mercury could be a portion of the F3 fraction.

There are limited data on methyl mercury in the Arthur Kill basin overall. The agency databases report only total mercury results. In the regional study sediment samples collected in Old Place Creek, methyl mercury was detected in all 10 samples (Appendix N, Table N-4). The highest percentage of methyl mercury was 0.39 percent, slightly higher than observed in South Branch Creek or the Arthur Kill.

Methyl Mercury

Methyl mercury was detected in 29 of the 32 sediment samples collected from South Branch Creek and in all six of the sediment samples from the Arthur Kill (Table 6-36). The percentage methyl mercury of the total mercury concentration was low (fractions of a percent) in all of the samples. In general, samples with higher total mercury concentration exhibited lower percentage methyl mercury. Sample SED-C-2-0.5-1.0 from South Branch Creek sediment showed the highest maximum total mercury concentration (901 mg/kg) and the lowest percentage methyl mercury (0.0015 percent). Arthur Kill results for maximum total mercury (30 mg/kg) and percentage methyl mercury were lower than the results from South Branch Creek.

6.6.2 Other Metals and Arsenic

Besides mercury, 22 metals and the metalloid arsenic were detected in sediment (Table 6-32). Of these, ER-L and ER-M values have been established for arsenic, cadmium, chromium, copper, lead, nickel, silver, and zinc. ER-L and ER-M exceedance frequency (Tables 6-33a and 6-33b, respectively) for these elements in South Branch Creek sediment samples was 35 to 98 percent, and 2 to 98 percent, respectively. In the Arthur Kill, ER-L values were exceeded in 17 to 100 percent of the samples and ER-M values were exceeded for three of those eight elements with an exceedances frequency of 17 percent. In the Northern Off-Site Ditch, ER-L values were exceeded in 50 to 100 percent of the samples and ER-M values were exceeded for four of those eight elements(arsenic, lead, nickel, and zinc) with an exceedances frequency of 17 to 100 percent. In the Southern Off-Site Ditch, ER-L values were exceeded in 33 to 50 percent of the samples and ER-M values were not exceeded.

Comment [PJT136]: Ditch Report

Nine metals had the highest concentrations in South Branch Creek and the lowest concentrations in the Arthur Kill. Arsenic concentrations were ten-fold higher overall in South Branch Creek than in the Arthur Kill, with a clear gradient from the Site (as discussed further below). Zinc and lead concentrations in South Branch Creek were approximately five times higher than in the Arthur Kill. Other metals had comparable concentrations in both sampled areas. Barium and cadmium had the highest concentrations in South Branch Creek, approximately ten-fold higher than in the Arthur Kill sediments.

Arsenic concentrations in the Northern Off-Site ditch were approximately 6 times higher than in the Arthur Kill. While the highest concentration of lead in the Northern Off-Site Ditch (242 mg/kg) was higher than the highest found in the Arthur Kill (161 mg/kg), the average concentrations of lead were comparable. Concentrations of other metals in the Southern Off-Site Ditch were comparable or lower than the Arthur Kill.

Comment [PJT137]: Ditch Report

Arsenic

The distribution of arsenic in sediments at various depths appears on Figures 6-26a through 6-26d, and the depth distribution appears in Table 6-34. Figure 6-28 shows the variation by station and depth. There is an area of marked arsenic elevation in the headwater section of South Branch Creek, with surficial sediments containing up to 4,250 mg/kg arsenic (SED-2). Similar elevated levels of arsenic were similarly detected in this area in the low marsh soils (Section 6.2.2). Arsenic in other surficial sediment samples in the Transect A area ranged from 118 to 2,640 mg/kg.

Moving toward the Arthur Kill, arsenic concentrations decrease dramatically; by Transect F, arsenic ranged from 13 to 47 mg/kg, and by Transect G, the concentrations were between 14 and 16 mg/kg. These levels are comparable to the regional arsenic concentrations in agency databases, which reported arsenic in surficial sediments between 10 and 100 mg/kg, most frequently in the range of 20 mg/kg (Section 2.10). Arsenic concentrations in sediments collected in the regional study from Old Place Creek averaged 35 mg/kg (Appendix N Table N-4). Therefore, the arsenic impact, as with mercury, attenuates to background by the mouth of South Branch Creek.

The elevated arsenic concentration observed in SED-2 appears to be a surficial condition, since the 0.5-1.0-foot and 1.0-1.5-foot samples at that location only contained around 100 mg/kg. A decrease with depth was also observed in SED-6 and SED-E-2, and to a lesser extent in SED-4 and SED-5. Other locations showed no decrement with depth.

The headwater area of South Branch Creek is clearly impacted by elevated arsenic. However, the arsenic enrichment appears to be a relatively isolated condition, as concentrations drop off rapidly with distance from the headwater. This apparent arsenic hot-spot does not likely result from on-site sources. Arsenic is not associated with chlor-alkali facilities and the sediment concentrations are considerably higher than arsenic levels observed in site soils within the former LCP production area. These data suggest that the source of arsenic in this area may have originated from another off-site source, possibly

Comment [PJT138]: SC#42

as a result of overland flow in the swale along the railroad tracks from the duPont and GAF sites. The elevated nature of the arsenic concentrations in this area relative to in upland on-site areas has already been described in Section 6.2.2 as part of the low marsh soils discussion. The fish tissue data collected at Transect A (see Section 6.7.2) further indicate that there is an unusual form of arsenic present in this area

Comment [PJT139]: SC#42

Arsenic concentrations found in the Northern Off-Site Ditch, presented in Figure 6-26e, do not appear to follow a clear pattern, with the highest concentration found in the middle B-transect, and comparable concentrations at the A and C transects. As discussed above, the concentrations are significantly elevated over the Arthur Kill, indicating a discharge of Arsenic into the Northern Off-Site Ditch. The highest concentrations of Arsenic in surficial soils on the LCP Site were found in the vicnity of the former Linde Hydrgoen Plant, located north of the ditch, indicating runoff from this area of the Site may have impacted the Northern Off-Site Ditch.

Comment [PJT140]: Ditch Report

Concentrations of Arsenic in the Southern Off-Site Ditch are comparable or lower than those found in the Arthur Kill indicating arsenic is not a concern beyond regional conditions.

Other Metals

Sediment results for other key metals (cadmium, copper, lead, nickel, and zinc) appear in Appendix J and Figures 6-29 through 6-32. In general, as illustrated in the figure, the concentrations of multiple inorganic elements show a high degree of correlation. Key pattern similarities include a decline in concentration with depth at SED-1, SED-C-2, SED-5, and SED-E-2 a concentration elevation at SED-B-1 with relatively consistent concentrations across the rest of Transect B; similar concentrations in all samples at SED-D-2 (all depths) and SED-D-3; and overall declining levels at the mouth of South Branch Creek and into the Arthur Kill. Mercury generally correlates with the other elements, but shows a more marked decline along South Branch Creek and into the Arthur Kill. The relative immobility may be due to binding of mercury with sulfides to form insoluble cinnabar.

The high correlation among multiple elements suggests that the distribution is related to sediment characteristics (e.g., grain size) and not to specific sources. Visual descriptions of the relative grain size of the sediment are presented in Appendix C.

Acid Volatile Sulfide/Simultaneously Extractable Metals (AVS/SEM)

AVS/SEM measurements are used as a general indicator of bioavailability of divalent metals (cadmium, copper, nickel, lead, mercury and zinc) in sediment. The major component of AVS; iron sulfide (FeS), reacts with those metals to form metal sulfides. The solubility of these metal sulfides is very low, and they are therefore not considered bioavailable. In sediments that contained a high level of reactive sulfide, the partitioning of divalent metals (Cd, Cu, Ni, Pb, Hg, and Zn) into the aqueous fraction (pore water), which represents the contact medium for aquatic life, will be minimized. Conversely, sediments with SEM greater than AVS are of potential concern with regard to bioavailability from sediment. Specifically, where the AVS/SEM ratio is less than one, there is a potential for the presence of soluble (bioavailable) metals.

Four samples from South Branch Creek had AVS/SEM ratios below one (Table 6-37): two from Transect D and two from Transect E. Similarly, all three samples from Transect G in the Arthur Kill had AVS/SEM levels below one. These results suggest the potential for bioavailability of divalent metals in these sediments, possibly due to the low levels of sulfides associated with coarser-grained substrate. In general, the AVS/SEM ratios do not appear to correlate with the total SEM concentrations. However, as discussed above, bulk concentrations of metals overall are elevated in the portion of ditch closest to the former production facility. ~~Therefore, it appears as if the total concentration of metals is of limited use in predicting bioavailability and ecological risk in this system. Rather, the presence of sulfides, likely associated with fine grained, depositional sediments, may be the controlling factor.~~The total bulk

Comment [PJT141]: SC#44

concentration of metals is not useful in predicting the potential for bioavailability since concentrations of sulfides, which control bioavailability, vary. In fact, the sample with the highest total SEM (SED-B-1-0-0.5 in South Branch Creek, 0.27 µmoles/g) is predicted to have minimal bioavailability due to high AVS, and, conversely, the samples in the Arthur Kill with low total SEM have low proportional AVS and therefore higher predicted bioavailability. The AVS/SEM calculation is based on the total of divalent metals and therefore accounts for competition among individual metals for binding sites. In addition, other variables such as total organic carbon may bind metals. For these reasons, therefore, it appears as if the total concentration of metals is of limited use in predicting bioavailability and ecological risk in this system. Rather, the presence of sulfides and other ligands, likely associated with fine-grained, depositional sediments, may be the controlling factor.

6.6.3 Organics

PCBs

Sediments collected from South Branch Creek had PCBs detected in 16 samples. Those PCBs were identified as Aroclor 1254 and Aroclor 1260 (Table 6-38, Figure 6-27a through 6-27d) which are the same as those observed in the on-site soils. The ER-L and ER-M concentrations for Aroclor 1254 are 0.023 mg/kg and 0.18 mg/kg, respectively. Of the samples with detectable PCBs, 18 percent exceeded the ER-L and 16 of the ER-M threshold.

None of the Arthur Kill sediment samples had detectable PCB concentrations. In the Transect A area, Aroclor 1254 was present, while in the locations closer to the Arthur Kill, PCBs were identified as Aroclor 1260. The maximum observed concentrations was 2.73 mg/kg and 1.12 mg/kg in the surficial samples at station SED-8 and SED-2, respectively. Other PCB results in South Branch Creek were well below 1 mg/kg, and the deeper samples contained less than the shallower (0-5-foot) samples. Overall, the Transect A area contains slightly higher PCBs than the remainder of South Branch Creek. This pattern, and the presence of AR 1254 (found upland), suggests that there could be a contribution from Site sources, although, as discussed in Section 2.6.1, other sources have historically discharged to this area as well. Additionally, regional studies of the Newark Bay estuary, as discussed in Section 2.10, have shown PCBs to be ubiquitous at concentrations similar to those found in South Branch Creek. These results indicate that there is the possibility of PCB contributions to South Branch Creek in the furthest upland transects.

Comment [PJT142]: SC#43

~~These results indicate that there is not a particular PCB contamination issue in South Branch Creek.~~

PCBs were not in the Off-Site Ditch samples with a single minor exception. One sample from the Southern Off-Site Ditch contained total PCBs at 0.0985 mg/kg. These results suggest that PCB contamination is not an issue in the Off-Site Ditches.

Comment [PJT143]: Ditch Report

PAHs

All eighteen analyzed SVOCs that are classified as polycyclic aromatic hydrocarbons (PAHs) were detected in sediment samples collected from South Branch Creek. The frequency of detection for these 18 chemicals in South Branch Creek samples ranged from 16 to 78 percent (Table 6-33a through 6-33b). ER-L/ER-M values have been established for 12 of these PAHs. The frequency of ER-L exceedances ranged from 4 to 39 percent. The ER-Ms were exceeded for 10 of these constituents, in 2 to 10 percent of the samples. The average total PAH concentration in South Branch Creek sediments was 8.3 mg/kg (Table 6-39 and Figures 6-33a through 6-33d). However, there was considerable variability: a relatively high value (27.6 mg/kg at SED-B-1-0-0.5) and the minimum (0.26 mg/kg at SED-B-2-0.5-1.0) were observed in the same transect.

In sediment samples collected from the Arthur Kill, 17 of the 18 PAHs were detected (2-chloronaphthalene was not detected). The frequency of detected chemicals ranged from 50 to

100 percent, with between 33 and 67 percent of samples exceeding ER-Ls and 17 to 50 percent exceeding ER-Ms. The average total PAH concentration in the Arthur Kill sediment samples (50.2 mg/kg)(Table 6-39) was nearly an order of magnitude higher than in South Branch Creek (8.3 mg/kg). The maximum observed total PAH concentration was in the shallowest sample at station F-3 (225 mg/kg), followed by 49.9 mg/kg and 19.9 mg/kg in SED-F1 and SED-F2, respectively. However, as with South Branch Creek, there was over two orders of magnitude variability within the Arthur Kill sample set.

In sediment samples collected from the Northern Ditch, 16 of the 18 PAHs were detected. The frequency of detected chemicals ranged from 67 to 100 percent. Of those detected, acenaphthene, anthracene, benzo(a)anthracene, chrysene, phenanthrene, dibenzo(a,h)anthracene, fluoranthene, and pyrene were detected above the ER-Ls. Only one sample for anthracene was detected above the ER-Ms. In sediment samples collected from the Southern Off-Site Ditch, 12 of the 18 PAHs were detected. The frequency of detected chemicals ranged from 17 to 100 percent. Of those detected only dibenzo(a,h)anthracene was detected above the ER-Ls. No samples for PAHs were detected above the ER-Ms.

Comment [PJT144]: Ditch Report

The average total PAH concentrations for the Northern Off-Site Ditch (3.2 mg/kg) and Southern Off-Site Ditch (0.75 mg/kg) were lower than found in the Arthur Kill (50.2), indicating there is not an elevated concern for PAHs in sediment in the Off-Site Ditches compared to the Arthur Kill.

The profile of PAH compounds (Figures 6-34a through 6-34d) is similar at most stations and depths in both South Branch Creek and the Arthur Kill, with a relatively even distribution of various compounds. Total carcinogenic PAHs (cPAHs) in sediments and cPAHs normalized to B(a)P) are shown on Figures 6-35a through 6-35d. This pattern is similar to what was observed in site fill (Section 6.1.6). The exception was the portion of South Branch Creek nearest to the Site (Transect A area), where chrysene and benzo(a)anthracene (B(a)A) represented a higher proportion of PAH species. The samples with the different profile were also ones in which higher total B(a)P equivalents were observed; otherwise, cPAH concentrations were generally comparable throughout South Branch Creek and the Arthur Kill, or higher in the Arthur Kill. It appears as if the cPAH presence in the Transect A area is from a source other than site fill or regional contribution. As discussed previously, this area has historically received flow from various non-site industrial sources, which appear to account for other contamination observed (notably arsenic).

PAHs are ubiquitous and the low-ppm concentrations observed in South Branch Creek are typical of industrialized waterways (ATSDR, 1995). Comparable concentrations were detected in the regional study samples collected in old Place Creek (which averaged around 5 mg/kg total PAHs; Table N-10). Furthermore, the elevated concentrations in the Arthur Kill sediments (Transect F) compared with South Branch Creek suggest a source unrelated to the Site. The PAHs detected in sediments (as well as low marsh soils) appear to be derived from regional sources, with the exception of some sediment in the Transect A area, which was derived in part from overland flow from neighboring properties.

PCDDs/PCDFs

Sediment samples were analyzed for 17 polychlorinated dibenzo-p-dioxins and -furans (PCDDs/PCDFs), 21 pesticides and herbicides, 51 non-PAH SVOCs and 46 volatile organic compounds (VOCs).

The full suite of analyzed PCDD and PCDF congeners was detected in nearly every sediment sample collected from South Branch Creek and the Arthur Kill (Table 6-32). These data were expressed by normalizing to the WHO (2005) TEFs to obtain TEQ. The TEQs have been calculated individually for PCDDs and PCDFs and are presented in Table 6-40 and Figures 6-36a through 6-36c. Discussion of TEFs in assessing risk also appears in the Human Health and Ecological Risk Assessments (Appendices P and Q).

The spatial distribution of TEQ values is presented in Figures 6-36a though 6-36c. The lowest TEQ observed in South Branch Creek was at SED-A-2-1.0-1.5 (2 ng/kg), and the highest at SED-C-3-0-0.5 (170 ng/kg) These differences may be related to variations in depositional conditions; for example, the Arthur Kill has been repeatedly dredged over the years. Furthermore, the PCDDs/PCDFs in each of the study areas are within the range of urban sediment background for Arthur Kill and are substantially lower than the levels in Newark Bay. These data support the conclusion that South Branch Creek is a receiving area for PCDD/PCDF deposition from regional sources in addition to the apparent contributions of PCDFs from the site.

The proportions of PCDFs in the South Branch Creek samples are dominated by PCDFs, particularly in the landward samples (Figures 6-36a through 6-36b). The mid-channel South Branch Creek samples reveal decreasing proportions of PCDFs while the sample collected within the Arthur Kill (Transect G) are comprised nearly entirely of PCDDs. These data suggest that a site related contribution of PCDFs in the South Branch Creek sediments that becomes more progressively dominated by the PCDDs of regional origin in the samples approaching Arthur Kill.

Pesticides/Herbicides

A variety of pesticide and herbicide compounds were reported in sediments: a total of 12 compounds were detected in the South Branch Creek sediments, with a detection frequency ranging from 2 to 49 percent. In the Arthur Kill, six pesticide and herbicide compounds were detected, ranging from 17 to 83 percent detection frequency (Table 6-32).

The highest concentration observed was dieldrin at 15 mg/kg in the 1.0-1.5 foot depth sample at station SED-B-2. This observation appears to be an anomaly, as other dieldrin observations were all below 0.012 mg/kg. The principal pesticides present in sediments are DDT and its daughter products, which were distributed throughout South Branch Creek and the Arthur Kill. There does not appear to be any consistent pattern or relationship to the Site, with highest concentrations in SED-B-2 (1.0-1.5 feet) followed by SED-E-2 (0.5-1 feet), SED-B-2 (1.0-1.5 feet), SED-F-3 (0-0.5 feet), and SED-G-2 (0-0.5 feet). The total DDT compound average concentrations were slightly higher in the Arthur Kill (1.2 mg/kg, Table 6-32) than in South Branch Creek (0.481 mg/kg), and the lack of an overall pattern indicates that the Site is not a source.

DDT and its daughter products DDE and DDD were also detected in both the Northern and Southern Off-Site Ditches, however their respective concentrations were lower than those found in either South Branch Creek or the Arthur Kill. The maximum detections of DDTin the Northern Off-Site Ditch was 0.244 mg/kg, and 0.0067 in the Southern off Site Ditch.

Comment [PJT145]: Ditch Report

Chlorinated Benzenes

As in surface water, a variety of chlorinated benzene compounds (chlorobenzene, 1,2- and 1,4-dichlorobenzene, and 1,2,4-trichlorobenzene) were reported in sediments. The maximal chlorinated benzene impact overall was in the Transect A area (up to 0.64 mg/kg chlorobenzene, 7.12 mg/kg 1,2-dichlorobenzene, 15.1 mg 1,4-dichorobenzene, and 11.8 mg/kg 1,2,4trichlorobenzene), although the maximum individual chlorobenzene concentrations were at Transect C (1.1 and 2.3 mg/kg, both at deeper locations at station SED-C-2). A somewhat lower chlorobenzene concentration (0.33 mg/kg) was observed in the 0-0.5-foot depth interval at this location. This pattern of increasing concentration with depth (which was not observed with other site-related constituents) suggests impacts from historic wastewater discharge and/or groundwater discharge that may be responsible for what was observed in sediments in this immediate area. Well MW-6S, which contained 16,200 mg/L of chlorobenzene, is within a couple hundred feet of the Transect C area of South Branch Creek. Similarly, benzene concentrations were highest in sediments at Transect C. Both chlorobenzene and benzene are more soluble than the di- and tri-chlorinated benzenes with lower k_{oc}s and would be expected to be more

mobile at the groundwater/surface interface, but then to have lower residence times in surface water. These properties could account for benzene and chlorobenzene having a more pronounced presence in the area of the presumed groundwater intrusion but lower persistence in sediments overall when introduced via run-off/suspended solids.

Chlorinated benzenes were detected in the Northern Off-Site Ditch at concentrations generally between those found in South Branch Creek and the Arthur Kill, with one notable exception. 1,4-Dichlorbenzene was detected on average at 2.5 mg/kg, compared to the average of 0.3 mg/kg South Branch Creek.

Comment [PJT146]: Ditch Report

Chlorinated benzenes were not detected in sediments in the Southern Off-Site Ditch.

Other Organics

Sixteen non-PAH SVOC compounds were detected in South Branch Creek, with a detection frequency ranging from 2 to 57 percent (Table 6-32). Fifteen SVOCs have been detected in the Arthur Kill. The detection frequency for these 15 SVOCs ranged from 17 to 50 percent. Chlorobenzene was detected at concentrations 2 to 3 orders of magnitude higher in South Branch Creek than the Arthur Kill.

Notwithstanding low levels of benzene and chlorobenzene, as discussed above, VOCs were not generally prevalent in sediments. Seventeen VOCs were detected in the South Branch Creek sediments, with a detection frequency between 3 and 84 percent (Table 6-32). In the Arthur Kill sediments, eight VOCs were detected, ranging from 17 to 67 percent. Sixteen (16) VOCs were detected in the Northern Off-Site Ditch, with a detection frequency between 17 and 100 percent. Three VOCs were detected in the Southern Off-Site Ditch, with a detection frequency between 17 and 67 percent. All detected VOCs had concentrations within the same order of magnitude. With the exception of chlorobenzene, acetone, and toluene, VOC concentrations were in the low ug/kg range and are considered trace.

Comment [PJT147]: Ditch Report

None of the organic compounds other than those discussed in Section 6.6.3.1 through 6.6.3.3 have ER-L and ER-M values established for them.

6.6.4 Sediment Toxicity

Four sediment samples were collected for concurrent sediment toxicity and bulk chemistry analysis. The samples were collected from Stations A-3, C-1, and E-1 in South Branch Creek (Figure 2-1). and Station W-2 in the tributary to Old Place Creek during the regional study (Appendix N, Figure N-1). The sediment toxicity report prepared by American Aquatic Testing of Allentown, Pennsylvania, appears in Appendix H.

Upon receipt and handling, the sediment toxicity testing laboratory, American Aquatic, reported that samples E-1 and C-1 produced mercury vapors (0.3 mg/m^3 and 0.09 mg/m^3, respectively) that could not be managed safely in the laboratory environment. Following extensive discussions with American Aquatic, several additional sediment toxicity testing facilities, and EPA/NJDEP, EPA authorized the elimination of these samples from the program on October 26, 2006. On October 27, 2006, American Aquatic transported these samples to the site where they were combined with the Investigational Derived Waste (IDW) for proper disposal.

Sediment toxicity testing using a 10-day testing protocol proceeded on sample A-3 and a regional control sample (W-2), as required by the method. Percent survival (56%) for the South Branch Creek sample was significantly lower than the laboratory control survival (95%). The site sample is considered acutely toxic because of the reduced survival in the acute testing conditions. Therefore, additional chronic testing was not performed.

Table 6-41 summarizes the 10-day survival rates for the marine amphipod (*Leptocheirus plumulosus*), along with sediment contaminant results, in the South Branch Creek and laboratory control samples. Table 6-41 excludes trace metals that were ND in both samples, common earth elements (aluminum,

calcium, magnesium, potassium, and sodium), and PCDDs/PCDFs. The PCDD/PCDF TEQ for sample A-3 is 27 ng/kg (within the range throughout South Branch Creek and the Arthur Kill).

The overall pattern of organic compounds in the two samples is similar and does not suggest that organic contamination accounts for the difference in amphipod survival between the two stations. The differences in observed sediment toxicity are more likely related to differences in mercury concentrations.

6.7 Biota

Fish (mummichog) and crab (fiddler crab) samples were collected in South Branch Creek, and the Arthur Kill in September 2006. Fish samples were collected at the approximate midpoint of each transect, at high tide, and crab samples were collected from each bank of the channel at each transect, at low tide (Figure 3-2 and Appendix N, Figure N-1). Fish and crab samples were rinsed, but not depurated and analyzed on a whole body basis for the list of COPECs (see Section 3.3.6). Detected analytes in tissue samples are presented in Tables 6-42a and 6-42b and Appendix J.

Specimens were inspected for obvious deformities. None were noted in the crabs. An anatomical abnormality was noted in only one individual fish, from sample MC-E. This specimen presented with a bulbous growth under the gill at the ventral side of the fish. The growth was a clear bladder, approximately twice the size of the fish's eye. There was some red visible inside, possibly blood. This particular fish measured 67 mm and weighted approximately 3.5 grams (a just above average size for this sample).

During exploratory seining as part of pilot studies, some mini krill and shrimp were observed. However, this method was not used for the specimen collection. Crabs observed were almost entirely *uca pugnax* (Atlantic marsh fiddler), with an occasional *uca minax* (red-jointed fiddler crab, estimated at 1-5% of the specimens encountered). Other species noted were blue crab (one notation, several observations, with larger specimens observed towards the mouth of South Branch Creek), black fingered mud crab (one observation of an apparent juvenile, 1 to 1 ½ inches long), and the occasional small unidentified crab.

No incidental observations of fish other than mummichog were noted. However, the fish collection efforts involved the use of minnow traps designed to capture small fish and were not intended to serve as a fish population survey tool.

Fish and crab whole body tissue was analyzed for 10 metals, methyl mercury, arsenic speciation compounds (arsenobetaine, arsenite, arsenate, monomethylarsonate, and dimethylarsinate), percent lipids, percent solids, and 156 PCB Congeners. Tables 6-42a and 6-42b present a summary of descriptive statistics for the fish and crab tissue samples, respectively; Figures 6-37a through 6-38b show the spatial distribution of mercury and arsenic in these samples.

Mummichog and fiddler crab samples were collected in the tributary to Old Place Creek during the regional study in September 2006. A summary of descriptive statistics for fish and crab tissue samples collected during the regional study can be found in Appendix N, Table N-12a , N-12b Figures N-9a through N-10b in Appendix N show the spatial distribution of mercury and arsenic in fish and crab tissue in samples from the regional study

The horizontal and vertical delineation of site-related constituents for biota is adequate to perform the analysis and selection of remedial alternatives as part of the Feasibility Study (FS). Additional delineation of biota may be performed, as necessary, as part of a Pre-Design Investigation (PDI).

Comment [PJT148]: GC#3

6.7.1 Mercury

The distribution of mercury concentrations in fish (Figure 6-37a) paralleled those observed in sediment, with the maximum concentration (7.68 mg/kg) reported in sample MC-C (Transect C), somewhat lower concentrations in Transect A (2.59 mg/kg in MC-A), a somewhat lower concentration in Transect B, and diminishing concentrations approaching the Arthur Kill. The one fish sample collected from the Arthur Kill (MC-F) contained 0.535 mg/kg mercury, comparable to the levels in fish collected from Transects D and E. The comparability of the patterns of mercury in fish tissue and sediment reflects the low mobility of this fish species and is consistent with bioaccumulation from the sediment in the immediate habitat area. However, since aquatic animals are consumed whole, for risk estimation purposes, whole body measurements are the most representative. The DERA estimates food chain exposures based on the whole body data.

Comment [PJT149]: SC#45

Typically, the majority of mercury in fish tissue would be present in the methylated form, as was the case in the samples where total mercury was relatively low. However, where fish tissue mercury was highest, the majority of mercury is not methyl mercury (Table 6-43a). Possibly the quantity of mercury in sediments in these areas has resulted in uptake of elemental or inorganic forms via a less typical mechanism. The higher levels of total mercury may result from incidental sediment in the gut.

The distribution of mercury in crab samples differed slightly from that in fish (Table 6-43b, Figure 6-37b). The maximum concentration (70.2 mg/kg) was detected in FC-C-1 (Transect C), but Transect B showed the next highest concentrations, followed by Transects A and D. The total mercury concentration detected in one of the two samples from the Arthur Kill (FC-F-2; 3.74 mg/kg) was comparable to that observed in samples from Transect A.

Tissue samples collected during the regional study (Old Place Creek) contained far lower mercury concentrations than those collected from South Branch Creek, with a maximum concentration of 0.15 mg/kg in fish and 0.19 mg/kg in crab (Appendix N, Tables N-13a and N-13b, Figures N-9a and N-9b).

Crab sample mercury reflected a lower percentage of methyl mercury, ranging from 0.77 to 78 percent in South Branch Creek (Table 6-43b and Appendix N Table N-13b). The crab samples revealed a clear negative relationship between total mercury and percentage methyl mercury. Overall the percentage methyl mercury in biota tissue was higher where the total mercury concentration was lower, although this pattern was more consistent in crabs than in fish.

Crabs and fish contained comparable levels of lipids, approximately 1 percent of body weight.

6.7.2 Arsenic

As with sediment, arsenic concentrations in both fish and crab tissue (presented on Figures 6-38a and 6-38b, respectively) exhibited a notable elevation in the MC-A and FC-A samples (Transect A). Concentrations elsewhere in South Branch Creek and in the Arthur Kill stations were relatively consistent (in the 3 to 6 mg/kg range for fish and the 7-10 mg/kg range for ~~arsenic~~ crabs). The regional study arsenic concentrations in fish tissue averaged 2.4 mg/kg (Table N-12a-_, Appendix N), somewhat lower. However, the regional study total arsenic crab data (average 9.9 mg/kg; Table N-12b) were comparable to those from South Branch Creek and Arthur Kill These data suggest that other than in the area of extremely elevated sediment, arsenic concentrations in crab tissue are not especially sensitive to the immediate sediment quality and may be homeostatically regulated.

Comment [PJT150]: SC#46

Speciation data for arsenic in fish tissue appear in Table 6-44. As predicted based on arsenic's known tendency to predominate in fish tissue in an organic form (ATSDR, 2007) a very small proportion of arsenic was inorganic (typically in the range of 1 percent or less), with the majority present as arsenobetaine (a nontoxic organic form). The exception was in the area of highly elevated arsenic

sediment concentrations, MC-A (Transect A), which showed 2-3 percent organic arsenic. In addition, the arsenic species that were analyzed (trivalent inorganic, pentavalent inorganic, arsenobetaine, dimethylarsinate, and monomethylarsonate) accounted for the approximate total arsenic present in most samples. At Transect A, however, the total arsenic concentration did not reflect the sum of these forms, with only 20 to 38 percent of the total arsenic accounted for (Table 6-44). These results suggest that the fish in Transect A have accumulated an unusual form of arsenic that is not typical in the environment, perhaps a complex organic form. This unusual arsenic contamination appears to have no relationship to the former chlor-alkali operations or ~~historic~~ anthropogenic fill and provides additional evidence of a separate, off-site source of arsenic into the head end of South Branch Creek.

Comment [PJT151]: ES#1

The arsenic tissue data were carefully reviewed and the appropriate moisture corrections were applied. Certainly there are precision issues with comparing the sum of speciated forms with the total for the analyzed element. This imprecision is exacerbated by the fact that the speciation analyses and the bulk analyses were performed by different laboratories. Nonetheless, each of the crab tissue samples in South Branch Creek and the Arthur Kill with the exception of the FC-A samples showed sums of arsenic species that accounted for between 70 and 120 percent of the total arsenic concentration, which is relatively good correlation given the inter-laboratory situation and the matrix effects. The arsenic forms in the FC-A samples, on the other hand, only accounted for 20 to 38 percent of total arsenic. Thus a majority of arsenic in those samples is not inorganic or in the most common organic forms, methylated and betaine, which typically accounts for the majority of arsenic in fish issue (Ackley, *et al.*, 1999). In summary, the arsenic therefore appears to be in some other organic form that is not commonly observed.

Comment [PJT152]: SC#47

The nature and source of the unidentified arsenic species is unknown. However, as detailed in earlier sections of this report (see Section 2.6.1), the headwaters area of South Branch Creek has historically received drainage from the duPont and GAF sites, which are known to have used and potentially discharged arsenicals. It is therefore entirely plausible that the arsenic present in the fish in this area of markedly elevated arsenic concentrations in sediment have accumulated an arsenical that is not commonly found.

6.7.3 Other Metals

Table 6-42a presents the descriptive statistics for fish tissue data for the other inorganic COPECs (barium, chromium, copper, iron, lead, manganese, vanadium, zinc). These eight metals were also detected in the fish tissue sample from the Arthur Kill. In the crab samples from South Branch Creek, these eight metals and arsenic were also detected in all 10 samples collected; as well in both crab tissue samples from the Arthur Kill (Table 6-42b).

Figures 6-40 through 6-41 illustrate the distribution of fish tissue inorganic results. Barium concentrations in fish tissue samples were highest in South Branch Creek samples, approximately 10-fold higher than the Arthur Kill. Fish tissue concentrations for iron, lead, manganese, vanadium, chromium and copper were the lowest in the samples collected from South Branch Creek. All metals but barium were detected in the same order of magnitude in both sample areas. Figures 6-42 through 6-44 show the distribution of inorganics in crab tissue. Barium, zinc, and lead concentrations in crab tissue samples were highest in South Branch Creek samples. Barium concentrations in crab tissue samples collected from South Branch Creek were 10-fold higher than the Arthur Kill. Crab tissue concentrations for iron, manganese, vanadium, and copper were the lowest in the samples collected from South Branch Creek. All other elements were present at comparable concentrations.

Overall, no pattern of elevated fish tissue concentrations is observed with these other metals (Figures 6-40 through 6-41). In crab tissue, barium, iron, lead, and zinc are present at higher concentration in South Branch Creek biota samples than in the Arthur Kill. As with mercury, this observation may reflect retention of impacted sediment in the gut rather than accumulation in tissue.

Further discussion of the biota-sediment accumulation factors appears in Section 6.8.

6.7.4 PCBs

Co-planar PCBs were analyzed in tissue. Of the 156 PCB congeners analyzed, 131 were detected in the fish tissue samples collected from South Branch Creek (Table-45, Figure 6-45). The PCB conger detection frequency ranged from 20 to 100 percent. In the sample collected from the Arthur Kill, 99 PCB congeners were detected. The total concentration of PCBs (sum of the average congener concentrations) was only slightly higher in South Branch Creek (344 ug/kg) than in the Arthur Kill (209 ug/kg), and comparable to the concentration of 278 ug/kg detected in samples from the regional study (Appendix N, Table N-12a). These concentrations are above the fish flesh criterion of 100 ug/kg that has been developed for the most sensitive receptors (mink), but below that estimated for less sensitive receptors such as rabbit (660 ug/kg; Newell, *et al.*, 1987).

The comparability of the PCB data in fish tissue from various locations indicates that PCB bioaccumulation from the South Branch Creek area is comparable with regional conditions.

In crab tissue, total PCBs in South Branch Creek specimens averaged 211 ug/kg, with 86 ug/kg in Arthur Kill samples (Table 6-46, Figure 6-46), the same total PCB concentrations as observed in the regional study crab samples (Table N-12b, Appendix N). The greater elevation in South Branch Creek crab but not fish tissue concentrations probably reflects the tendency of undepurated crabs to retain sediment in their guts, thereby more closely reflecting the immediate sediment quality.

6.8 Measures of Biological Accumulation

6.8.1 Bioconcentration Factors (BCFs)

Bioconcentration factors (BCFs) reflect the accumulation of contaminant in tissue from water. They are estimated as follows:

$$\mathrm{BCF}\left(\mathrm{l\,water}/\mathrm{kg\,tissue}\right)=\frac{\mathrm{mg}/\mathrm{kg\,tissue}}{\mathrm{mg}/\mathrm{l\,water}}$$

Based on the average total mercury concentration in fish and surface water from Transects A through E (2.6 mg/kg and 3.9x 10^{-3} mg/l, respectively; see Tables 6-42aand 6-30 for the data), the bioconcentration factor (BCF) from water to fish is approximately 700. Using methyl mercury results (0.68 mg/kg in fish and 5.5 x 10^{-6} µg/L in fish and water, respectively), the approximate BCF for methyl mercury is 1 x 10^{5}. Using the samples from Transect F to represent the Arthur Kill (no fish were obtained at Transect G), the total and methyl mercury BCFs are estimated at 400 and 4 x 10^{5}, respectively. These BCFs are comparable with those that have been reported in the literature (see Section 7.2) and indicate that bioaccumulation is occurring despite the tiny proportion of total mercury present in surface water that is methylated.

6.8.2 Biota-Sediment Accumulation Factors (BSAFs)

Tissue accumulation is not typically a concern for metals. However, the USEPA previously expressed concern about the potential for tissue accumulation and specifically requested tissue analyses for 10 metals. To address the resulting data, Biota-Sediment Accumulation Factors (BSAFs) were calculated for these metals. The BSAFs provide an estimate of the uptake of chemical constituents from sediment to biological tissue by taking the lipid-normalized concentration in organisms divided by the organic carbon-normalized concentration in sediments. The BSAFs for metals are reported as:

$$BSAF\left(\frac{kg\ sediment}{kg\ tissue}\right)=\frac{\frac{mg}{kg\ tissue}}{\frac{mg}{kg\ sediment}}$$

And the BSAFs for total PCB Congeners are reported as:

$$BSAF\left(\frac{kg\ OC}{kg\ lipid}\right)=\frac{\frac{mg}{kg\ lipid}}{\frac{mg}{kg\ OC}}$$

These BSAFs are based on the undepurated data, meaning that the total tissue concentrations reflect sediment retained in the gut. The BSAFs therefore may not provide an accurate representation of contaminants accumulated in tissue. However, mummichog and crab are prey species consumed whole. Therefore, the BSAFs estimated based on the undepurated results reflect the food chain impacts.

The BSAFs for fish and crab tissue are presented in Tables 6-46a and 6-46b, respectively. They are highly variable but all well below 1, indicating that the tissue contains lower concentrations than sediments in the corresponding areas. Thus biomagnification into tissue is not occurring from sediment.

The squares of the regression coefficients (R^2) values are also shown in the tables. These values show the statistical strength of association between the sediment concentration and the tissue concentration; they do not indicate the magnitude of the BSAF (the slope of the relationship, or extent to which tissue will change in response to sediment concentrations). Specifically, the R^2 value (0-1) represents the proportion of change in one variable that can be predicted by the other variable. Note that R^2 values only give a guide to the "goodness-of-fit" and do not indicate whether an association between the variables is large or statistically significant. R^2 values below 0.69 are considered not to be strong enough to conclude that there is any substantial association.

The analytes with R^2 values above 0.69 for fish in South Branch Creek were total PCBs, barium, and lead. The analytes with the R^2 values above 0.69 for crab in South Branch Creek were arsenic and total PCBs. These results suggest that the tissue concentrations of these analytes are associated to some extent with sediments, although none of the relationships are strong.

6.8.3 Mercury

The highest fish BSAF for mercury in South Branch Creek is 0.023 in Transect B. In the Arthur Kill, the fish BSAF for mercury is 0.0089 (Table 6-46a). In South Branch Creek, the R^2 value is 0.68, below a level indicating a meaningful relationship. These BSAFs indicate minimal dependence of fish tissue concentrations on sediment concentrations within small geographic zones. However, the concentrations of mercury in fish do indicate an overall impact from mercury presence in sediments, since the levels are well above those that have been reported in various New York Harbor estuary samples (USEPA, 1997), which were typically in the 0.2 mg/kg range. The concentrations reported by the USEPA are similar to those observed in the regional study conducted in Old Place Creek, where concentrations in fish ranged up to 0.15 mg/kg, thus indicating that Old Place Creek is representative of regional conditions.

The highest crab BSAF for mercury is 0.31 at station B-2 in South Branch Creek (Table 6-46b). In the Arthur Kill, the highest crab BSAF for mercury is 0.13. The highest crab BSAF for mercury in the regional study is 0.1 at station W-2. Crab BSAFs decrease as mercury sediment concentrations increase, suggesting a saturation of the bioaccumulation mechanism. In cases where exposures impact population dynamics, the appearance of decreases in accumulation with increasing concentrations can be indicative of lethality in the higher-exposed individuals. This phenomenon does not appear to be the case in South Branch Creek. The populations of both fish and crabs in South Branch Creek were observed to be robust and healthy. There were no observed die-offs or apparent deformities associated

Comment [PJT153]: SC#48

with the higher-mercury concentrations zones, nor evidence of fewer individuals. Therefore, lethality with increasing concentrations is not a likely explanation for decreasing BSAFs with concentration. Note the uptake functions for mercury (and other metals) in invertebrates have been shown to be logarithmic and generally follow the algorithm log(y) = a' + b log(x), where y and x represent the tissue and sediment concentrations, respectively, and the BSAF is estimated as y/x (see Bechtel Jacobs, 1998[7]). Thus mercury BSAFs show a declining relationship with concentration.

No correlation between the crab BSAFs and the sediment mercury concentration was observed in South Branch Creek. As with fish, however, crab mercury tissue burdens in South Branch Creek, which ranged up to 70 mg/kg, were well above mercury invertebrate concentrations that have been reported regionally (0.1 to 0.3 mg/kg; USEPA, 1997), indicating that even if individual sample concentrations cannot be predicted based on localized sediment levels, there is bioaccumulation overall from South Branch Creek sediments.

6.8.4 Other Metals

As mentioned above, metals other than mercury with the high R^2 values for fish in South Branch Creek were barium (0.89) and lead (0.78). The highest fish BSAF for metals other than mercury in South Branch Creek is 0.56 for barium in Transect C (Table 6-46a). The R^2 value for this BSAF barium is 0.89, indicating a strong relationship between the sediment concentration and tissue concentration. As mentioned above, the other metals with the high R^2 values for fish in South Branch Creek were barium (0.89) and lead (0.78).

~~Fish BSAFs for barium, manganese, vanadium, zinc, and copper decrease as concentrations for those metals in South Branch Creek sediments increase.~~ However, the fish BSAFs for barium (as well as for manganese, vanadium, zinc, and copper) decrease as concentrations for those metals in South Branch Creek sediments increase. These observations suggest a saturation mechanism where the proportion of uptake decreases as the concentrations increase. As stated above, failure to thrive among higher-exposed individuals is an unlikely explanation for the negative relationship between BSAFs and sediment concentration. In addition, barium is not a bioaccumulative constituent. It is not identified by EPA as a Persistent Bioaccumulative and Toxic (PBT) chemical. A mean bioaccumulation factor (BAF) for earthworms of 0.088 has been reported[8] ; BAFs for small mammals range from 0.014 to 0.019[9]. These low BAFs indicate no propensity for barium to bioaccumulate.

The highest crab BSAF for metals other than mercury in South Branch Creek is 5.6 for barium in Transect A (Table 6-46b). This is also the highest observed crab BSAF for metals. In the Arthur Kill, the highest crab BSAF is 2 for copper. The highest crab BSAF for metals in the regional study is 5.0 at Transect X, also for arsenic. The R^2 value for arsenic is 0.96, indicating a strong relationship between the sediment concentration and tissue concentration and therefore a high confidence in the calculated BSAF. As mentioned above, the other constituent with a high R^2 value for crab in South Branch Creek is total PCBs. In the regional study none of the analytes had R^2 values for crab above 0.69, indicting no meaningful association between tissue and sediment.

Comment [PJT154]: SC#48

Comment [PJT155]: SC#48

Comment [PJT156]: SC#48

[7] Bechtel Jacobs, 1998. Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation. Oak Ridge National Laboratory, Oak Ridge, TN. BJC/OR-112.

[8] Sample, B.E. et al, 1998. Development and Validation of Bioaccumulation Models for Earthworms. Oak Ridge National Laboratory, Oak Ridge TN. ES/ER/TM-220.

[9] Sample, B.E. et al, 1998. Development and Validation of Bioaccumulation Models for Small Mammals. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-219.

6.8.5 Total PCB Congeners

PCB sediment data were analyzed as Aroclors, while tissue data were analyzed as PCB congeners. These data sets are not directly comparable, and therefore BSAFs were not estimated using the measured tissue data. The Baseline Ecological Risk Assessment (BERA: Appendix Q) estimated total Aroclor 1254 and 1260 concentrations in tissue using literature-derived BSAFs (1.99 for crab and 2.14 for fish). Please refer to the BERA for additional discussion and application of these BSAFs.

6.9 Summary of Overall Nature of Contamination

6.9.1 Soil Summary

Contaminants derived from manufacturing activities at the LCP site have directly impacted soil quality as a result of site operations. Contaminated soil provides a historic and potential ongoing source of contamination of other media. The soil impacts are primarily observed in the shallow anthropogenic fill soils given the fact that the discharges likely occurred on the ground surface. The underlying natural soils, including the tidal marsh deposits and glacial till, are impacted to a much lesser degree than are the anthropogenic fill soils.

Overall, the only soil constituents that clearly appear to have originated from historic chlor-alkali site operations are mercury, PCNs, and HCB and, to a limited extent, PCDFs. PCBs are also a site-related constituent due their potential presence in electrical equipment on the site. Other constituents that are present in the anthropogenic fill and/or represent regional background conditions include arsenic and other metals, PCDDs, PAHs, BTEX, chlorobenzene, and several other miscellaneous organics.

Site related contaminants in soil have been horizontally delineated to the north and west where the LCP property abuts the LPH Site, which itself has been investigated and has received an NFA designation for soil contaminants (Section 2.1.2). Soil contaminants are bounded to the east by South Branch Creek. Contamination in fill material has not been delineated in the area located south of the Linde Hydrogen Plant, however, given the findings of the Off-Site Ditch Investigation have shown site related contaminants in the Northern Off-Site Ditch. It is reasonable to conclude shallow soil contamination in the vicinity of the Linde Hydrogen Plant is bounded to the south by the Northern Off-Site Ditch, particularly given the unimpacted condition of the Southern Off-Site Ditch. Site related contaminants have been vertically delineated as evidenced by data from the underlying Tidal Marsh Deposits and Glacial Till soils.

Comment [PJT157]: GC#3

Site Operations Constituents

Mercury is the primary site-related contaminant and is present in soil as a result of the chlor-alkali manufacturing process at the LCP site. Elevated levels of mercury, including visible elemental mercury, were found in the anthropogenic fill soils throughout nearly the entire site. The highest mercury concentrations were observed in and around the former production area near Buildings No. 230, 231, and 240, including beneath the buildings. Substantial attenuation of mercury concentrations was observed in the underlying natural soils. No exceedances of NJ NRDCSRS were observed in the glacial till except beneath Building No. 240. The mercury in soil is relatively immobile given the fact that it is primarily present in relatively insoluble forms including mercury sulfide and elemental mercury.

PCBs (Aroclors 1254 and 1260), PCN, and HCB are widely distributed across the site within the anthropogenic fill. Some occurrence of PCDFs may be related to the site. PCBs are associated with the electrical equipment that was formerly used on the site. PCNs, HCB, and sometimes PCDFs formation are formed as byproducts in chlor-alkali plants through the reaction of the chlorine with the graphite anodes. The decreasing vertical distribution of PCBs, PCNs, HCB in the fill suggests on-site surface

sources of these other constituents. The site-related occurrences of PCBs, PCNs, HCBs, and PCDFs are generally co-located with samples containing elevated levels of mercury, as shown on Figure 6-47.

Anthropogenic ~~Historic~~ Fill and Regional Constituents

Other constituents that are not related to manufacturing activities at the site are frequently detected in the site soils, particularly in the anthropogenic fill. These include arsenic and other metals, PCDDs, PAHs and other organics, including chlorobenzenes. The ubiquitous presence of arsenic, other metals and PAHs in areas with no production history, the presence of anthropogenic fill, the absence of a decreasing concentration gradient within the fill, and the absence of an association with the known sources of contamination lead to the conclusion that the occurrences are not associated with LCP site operations; rather they are associated with the presence of anthropogenic fill materials and/or neighboring operations as shown on Figure 6-48. Arsenic concentrations found in soil in the vicinity of the former Linde Hydrogen Plant, as well as the upstream areas of South Branch Creek, are elevated beyond the concentrations found typically throughout the sitewide anthropogenic fill material. Arsenic is not a site-related process chemical; however locations where arsenic concentrations are elevated beyond those found in anthropogenic fill are sufficiently co-located with process related contaminants and therefore would be subject to remediation.

Sporadic elevated concentrations of chlorobenzenes and other VOCs are observed in anthropogenic soils. Substantially higher concentrations of chlorobenzenes are observed in the deep fill as compared to the shallow fill which suggests the absence of an on-site source. ~~Chlorobenzenes were commonly used as a raw material in the manufacture of dyes at the adjacent GAF site and are a possible source in the fill that may have originated from that site.~~ Chlorobenzenes (mono, di, and tri) were extensively used in the manufacture of organic dyestuffs and pigments at the GAF site, as described in the GAF RI Report, (Eckenfelder, 1991). As a result, chlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, and 1,2,4-trichlorobenzene are among the most commonly detected organic constituents in soil and groundwater at the GAF site. Chlorobenzenes were generally not detected in the underlying tidal marsh deposits.

6.9.2 Low Marsh Soil Summary

Low marsh soils represent native tidal marsh material that has likely been overlain by deposition of aquatic sediments during tidal surges. Samples collected were shallow (0-0.5- feet deep) and therefore likely reflect the sediment deposition component.

In general, the low marsh sample contamination indicates higher association with sediment than with marsh deposit soils in the upland portion of the site. Mercury was highest in the low marsh samples near Transect C, not along the portion of South Branch Creek closest to the site. Furthermore, the total mercury present in low marsh soils was higher overall than in the tidal marsh deposits upland on the site (Figure 6-1c).

Other site-related constituents were not prevalent in the low marsh material. Hexachlorobenzene, and PCBs, which were present throughout surficial site soils, were minimally detected in low marsh soils. Conversely, arsenic concentrations were higher in low marsh soils than anywhere on site. PCDDs and PCDFs were higher in locations approaching the Arthur Kill than closer to the Site.

The contaminant distribution is similar to that observed in sediments, reflecting only mercury as a principal contaminant of site origin. Additional discussion of the low marsh soils in the context of overall site contamination appears as part of the sediment evaluation (Section 6.6.4).

Comment [PJT158]: ES#1

Comment [PJT159]: SC#50

Comment [PJT160]: SC#50

Comment [PJT161]: SC#51

6.9.3 Groundwater Quality Summary

Surface Water Quality Standards (SWQS) are utilized herein for comparison to bedrock groundwater quality as the bedrock water-bearing zone was formally reclassified as Class III-B due to its natural saline conditions. The SWQS are utilized, in the absence of a NJDEP-approved method for the development of alternate groundwater quality criteria, to be protective of surface water quality in South Branch Creek and the Arthur Kill as a result of discharging bedrock groundwater. The overburden groundwater quality data are compared to the Groundwater Quality Standards (GWQS) given that its classification remains as Class IIA.

~~Alternative groundwater quality criteria (AGWQC) are proposed and utilized herein as the groundwater meets the requirements for Class III-B due to its natural saline conditions. The AGWQC are proposed for both the overburden and bedrock water bearing zones. The AGWQC are developed to be protective of surface water quality in South Branch Creek and the Arthur Kill as a result of discharging groundwater and potential risks to human health resulting from direct contact by future construction workers.~~

The source of groundwater contamination within the overburden water-bearing zone is the dissolution of various constituents from the site soils. Accordingly, mercury is the only site-related contaminant that is generally found in groundwater, albeit at relatively low concentrations. The other site-related constituents, including PCBs, PCNs, HCB and PCDFs, are relatively insoluble and are not detected in groundwater.

Other detected groundwater constituents including arsenic and other metals and several VOCs and SVOCs are not site related. The highest VOC/SVOC detections are attributed to historic off-site sources including the adjacent NOPCO site and the historic wastewater conveyance from the former GAF site. However, many of these same compounds may occur from their dissolution from the anthropogenic fill. Mercury levels in overburden groundwater is either detected at relatively low concentrations or is not detected, and is generally limited to areas of the site in which very high levels of mercury are observed in the soils. These findings provide additional evidence that mercury in soil is present in primarily insoluble forms. Moreover, mercury in groundwater was largely undetected around the perimeter of the closed RCRA unit, demonstrating that that unit is not a source of mercury in groundwater.

Most groundwater constituents in bedrock are undetectable except in the northwest area of the site, upgradient of the LCP production area. Mercury, benzene, and chlorobenzenes are detected within the zone in which the GAF groundwater extraction system has been shown to induce bedrock groundwater flow from the neighboring GAF site. However, bedrock groundwater is captured and treated by the adjacent GAF groundwater remediation system. None of the detected groundwater constituents form laterally continuous plumes across the site, regardless of whether or not they are related to the site production areas. These sporadic patterns reflect the relatively sporadic distribution of various source materials in the soils (e.g., VOCs).

No free phase organic liquids were observed in the groundwater column in either overburden or bedrock monitoring wells.

Site-related contaminants and arsenic in groundwater have been vertically and horizontally delineated in both the overburden and bedrock water bearing zones. Delineation of non-site related contaminants benzene and chlorobenzene in the overburden groundwater is not complete in the southeast direction, towards the NOPCO facility. No further delineation is necessary of site related contamination in groundwater.

Comment [PJT162]: GC#2

Comment [PJT163]: GC#3

6.9.4 Sediment and Surface Water Quality Summary

South Branch Creek and the Northern Off-Site Ditch exists within the regionally contaminated Arthur Kill system and has also been impacted by numerous localized historical inputs in addition to the LCP site. Thus contamination observed is attributable to impacts from four general sources: site operations; contamination on site due to contaminated soil/fill; discharges from non-site sources; and regional contamination.

Mercury, present throughout sediment and surface water in South Branch Creek and the Northern Off-Site Ditch, is site related. Shallow groundwater in the vicinity contains little or no mercury, so sources are historically related to direct discharges and surface run-off. There is no substantial ongoing drainage from the site to South Branch Creek. It is not specifically known to what degree runoff from the LCP site drains into the Northern Off-Site Ditch although this appears to be a likely transport pathway. Mercury appears in suspended particulates in surface water as well as low marsh soil, which has likely been impacted by upland sediment deposition. Mercury concentrations are highest in the areas of historical inputs, namely Transect A, which has received drainage from multiple sources over the years, and the former City of Linden sewer pipe at Transect C. Mercury concentrations attenuate with distance from the site and are comparable to regional Arthur Kill background by the confluence with the Arthur Kill. Other site-related constituents reported in sediments are low-level PCBs, PCDFs, and chlorinated benzenes, all of which show a similar gradient leading to background or undetected concentrations in the Arthur Kill. Site-related sources of mercury within the South Branch Creek sediment and surface water are primarily related to historic stormwater discharges from the LCP site. Shallow groundwater that discharges to South Branch Creek contains little or no mercury, such that groundwater is not an ongoing mercury migration pathway to South Branch Creek. Furthermore, stormwater discharges from the site to South Branch Creek have been poorly defined since about 1976. Given the estimated stormwater discharge velocities and volumes, ongoing mercury migration via this pathway has been and likely continues to be minimal. The concentration gradient of Mercury found in the Northern Off-Site Ditch is less defined due to the parallel configuration of the Ditch alongside the operations areas of the Site.

As described in Section 2.6.1, no defined stormwater drainage system currently exists at the LCP site. Large areas of the site are currently undrained given the remedial action on the adjacent GAF site in 2003 and the cessation of stormwater collection and treatment on the LCP site upon cessation of operations. The concrete drainage channels on site are now filled and the connection to South Branch Creek was obstructed at some point in the past. Areas that do drain to South Branch Creek and the unnamed ditch likely do so relatively slowly given the lack of drainage structures and the nearly flat grades on the site. Ponding occurs in several areas of the site for long durations depending on rainfall intensity and duration.

Arsenic concentrations in South Branch Creek sediment, low marsh soil, and surface water are markedly elevated in the Transect A area, but the elevated levels relative to those detected on site indicate that arsenic is present due to non-site sources (historic drainage along the railroad tracks from other sites). Arsenic impacts also attenuate with distance along South Branch Creek, reflecting the generally low sediment mobility in the ditch. Arsenic concentrations in the Northern Off-Site Ditch, while lower than found in South Branch Creek, are elevated beyond those found in the Arthur Kill, indicated historic discharge to the Ditch from the LCP site. Other contaminants (metals, PAHs, and CDDs) show minimal relationship to the site and appear to be of regional origin.

Site related contaminants in South Branch Creek have been delineated to levels consistent with regional sediment contaminant conditions in the Arthur Kill. Given the fact that the sediment investigation included the full extent of South Branch Creek, no further delineation of sediment contamination is necessary.

Comment [PJT164]: Ditch Report

Comment [PJT165]: Ditch Report

Comment [PJT166]: Ditch Report

Comment [PJT167]: SC#53

Comment [PJT168]: Ditch Report

Comment [PJT169]: Ditch Report

Comment [PJT170]: Ditch Report

Comment [PJT171]: GC#3

The investigation of sediments in the Northern Off-Site Ditch has not yielded complete delineation of Site Related contaminants in the upstream direction. It is recommended that further delineation sampling, as necessary, would be conducted as a part of a remedial pre-design investigation (PDI). The downstream end of the Northern Off-Site Ditch is believed to be connected via a culvert to South Branch Creek. Further delineation in the downstream direction, toward South Branch Creek, is not necessary.

The concentrations of contaminants in the Southern Off-Site Ditch are significantly lower than those found in the Northern Off-Site Ditch or South Branch Creek, and are more similar to regional conditions found in the Arthur Kill. Based upon the analytical results, the Southern Off-Site Ditch does not appear to have been impacted by contaminants relating to the LCP Site.

Comment [PJT172]: Ditch Report

Investigation of both South Branch Creek and the Northern and Southern Off-Site Ditches has shown that the presence of contaminants in Surface Water is driven primarily by suspended particles in the water column. Due to the dynamic nature of the medium and the tidal fluctuations, meaningful delineation of contaminants in surface water is not possible.

Comment [PJT173]: GC#3

Section 7

Contaminant Fate-and-Transport

This section addresses the routes by which LCP site-related chemicals of concern (COCs) may migrate and transform in the environment. The evaluation considers the observed form and distribution of COCs in site-related media in the context of the chemical and physical behavior described in the literature. The primary focus is mercury; however, other COCs are addressed, particularly where their fate and distribution may differ from that of mercury.

7.1 Routes of Migration

The LCP site was the location of a mercury cell chlorine (chlor-alkali) facility that operated for approximately 30 years starting in 1955 or 1956 until 1985. Chlorine cells manufacture chlorine gas from sodium chloride using liquid mercury as a positive electrode (cathode):

$$2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH \text{ (caustic soda)}$$

Because of its high volatility, mercury loss occurs throughout the process, with the hydrogen gas, caustic soda and the wastewater stream containing small amounts of mercury. Mercury vapor escapes atmospherically. A fairly recent investigation at an active chlor-alkali facility demonstrated that approximately 0.5-1% of mercury was released as reactive gaseous mercury (RGM) and the remainder was particulate bound; however, studies from other plants have reported substantially higher RGM fractions. The RGM fraction, likely composed of mercury chloride homologues, has been identified as the mercury component of greatest environmental concern due to its solubility and depositional tendency. Total gaseous mercury (TGM), on the other hand, tends to mix rapidly into the troposphere, resulting in less of a localized presence (Wängberg, *et al.*, 2003).

Mercury release over the operational life of the facility was both atmospheric and via ground discharge (wastewater, spills). Compared with other atmospheric sources of mercury, chlor-alkali facilities are associated with low dispersion and therefore concentrated localized mercury impacts. As discussed in Section 6.1 and as shown on Figures 6-1a through 6-1d, there is substantial visible elemental mercury presence in the immediate area of the former plant. Following deposition, three major fate mechanisms appear to account for the current mercury presence:

- **Persistence:** mercury remains where it was deposited (as indicated by the current visible mercury presence);
- **Run-off:** particulate-bound mercury has been entrained via overland and piped discharges to surface water systems where it exists as sediment or suspended in surface water particulates; and
- **Vertical migration:** mercury has moved into the subsurface and/or partitioned into groundwater

These processes also account for the disposition of other LCP site-related COCs. The relative importance of these processes and their historical and current status is detailed further below. Additional fate mechanisms that have likely accounted for contaminant loss from the LCP site area are also discussed.

Table 7-1 summarizes key physical and chemical properties that affect fate-and-transport behavior for principal LCP site COCs. Several mercury species are shown although, as discussed further below, information on mercury speciation is limited to fractionation data. The key characteristics affecting fate-and-migration are solubility, volatility (Henry's Law Constant), and potential for adsorption (K_{oc}).

7.1.1 Volatilization

Volatilization (the conversion of a liquid or solid to gas) occurs with substances that have a Henry's law constant (H) greater than 10^{-3} atm-m^3/mol; those with H values below 10^{-5} atm-m^3/mol have low volatilization potential. Elemental mercury is the most volatile form of mercury.

~~Volatilization is~~ When initially deposited, mercury is the most volatile, but is converted to more stable, less volatile forms over time, so the significance of the volatilization pathway decreases (Renneberg and Dudas, 2001; Beldowski and Pempkowiak, 2007). However, volatilization remains a significant fate mechanism for mercury from all media (USEPA, 1997; Bollen, *et al.*, 2008). When initially deposited, mercury is the most volatile, but is converted to more stable, less volatile forms over time, so the significance of the volatilization pathway decreases (Renneberg and Dudas, 2001; Beldowski and Pempkowiak, 2007). Humic matter, even at low concentrations, limits mercury emission from soil, with even a very small quantity of organic matter exerting a strong inhibitory effect (Mauclair, *et al.*, 2008).). Photoreduction of mercury may occur at the soil/sediment surface, converting Hg2+ forms to the volatile HgO. In addition, plants can take up mercury and discharge it to the atmosphere through transpiration (Gustin et al, 2004; Lindberg et al, 2002).

High rates of mercury degassing have been measured from soils around chlor-alkali sites (Wängberg, *et al.*, 2003). ~~This observation is consistent with the observed presence of elemental (volatile) mercury in areas of the LCP site.~~ Soil gas results for the site (see Table 6.23) indicate that both mercury and VOCs are volatilizing into the vapor phase. Mercury vapors were detected in all four (4) of the samples that were tested at average and maximum concentrations of 1 ug/m^3 and 2.5 ug/m^3, respectively; however, none of the observations exceeded the USEPA soil vapor screening level of 3 ug/m^3. Thus while the volatilization pathway for mercury is complete, partitioning from the soil to vapor phase does not appear to be a major fate mechanism.

Exceedances of VOC screening levels were sporadic and limited to five compounds. These observations are consistent with the sporadic presence of VOCs in bulk soil. VOCs are not significant COCs at the LCP site, but sporadic presence of BTEX, chlorobenzene, chloroform, and TCE in both soil and soil gas indicates that these constituents are partitioning from the soil into the air phase. Once in air, they will dissipate rapidly. Residence times for VOCs in aquatic systems are expected to be short, as volatilization will be the dominant fate mechanism.~~Volatile organic compounds (VOCs) are not significant COCs at the LCP site, but sporadic presence of BTEX, chlorobenzene, chloroform, and TCE in both soil and soil gas indicates that these constituents are partitioning from the soil into the air phase. Once in air, they will dissipate rapidly. Residence times for VOCs in aquatic systems are expected to be short, as volatilization will be the dominant fate mechanism.~~

Semivolatile organic compounds (SVOCs) such as hexachlorobenzene (HCB), have some potential for vaporization, but volatilization is not expected to be a major fate pathway for SVOCs under most environmental conditions. Less than 1 percent of HCB in the environment is expected to be distributed to air, indicating low volatility (USEPA, 2006). Volatilization of dichlorobenzenes from surface soil can be significant, although adsorption will limit that process (ATSDR, 2006). The volatility of PCNs as a class varies, but the lower-chlorinated (mono- and di-) homologues present at the site may have some tendency to volatilize compared with more chlorinated congeners (Falansyz, 1999). Higher-chlorinated PCBs (such as AR 1254) are subject to extremely low volatilization from soil surfaces, although long-term total volatilization loss may be significant due to their persistence (Spectrum, 2008). PCBs show a higher tendency to partition from water to air than do other hydrophobic chlorinated organics such as dioxins and furans (USEPA, 2008b), although lower-chlorinated chlorinated dibenzo-p-dioxins and –furans (CDDs/CDFs) may volatilize from surface water (ATSDR, 1998).

Due to generally low volatility, soil vapor measurements of PCBs and SVOCs is not routine and were not included in this RI.

Comment [PJT174]: SC#55

Comment [PJT175]: Revised Section 7

Comment [PJT176]: SC#54

Comment [PJT177]: Revised Section 7

7.1.2 Adsorption

Adsorption, the binding of molecules or particles to a surface, is a significant attenuation mechanism for environmental migration. In soil, most mercury is bound to fines and organics (Beldowski and Pempkowiak, 2007; Bollen, *et al.*, 2008). Mercury is a "class B" chalcophile element, meaning that has a very strong affinity for sulfur groups in organic matter (Renneberg and Dudas, 2001; McComish and Ong, 1988; Bollen at al, 2008). The formation of mercury sulfides is important because these compounds are highly insoluble and immobile. Sulfide formation is known to occur in even mildly reducing environments. Deeper sediments are expected to be anoxic and therefore more reduced than the surficial layer, which is subject to tidal flushing.

Even following adsorption, it is possible for mercury to volatilize (Renneberg and Dudas, 2001). However, in coastal sediments (Beldowski and Pempkowiak, 2007), as in-soil, a large proportion of mercury is bound to humic substances. As discussed above, this adsorption limits volatilization. Competition from chloride in brackish or saline water can greatly decrease the proportion of mercury bound to humic substances (McComish and Ong, 1988). Methylation is generally low in most soil but in reducing environments sulfate-reducing bacteria can convert the Hg into methyl mercury., which occurs to a small but significant extent in reduced wetland soils and sediment (USEPA, 1997). Methylation can also make mercury less available for adsorption. Methylation is discussed further in Section 7.1.6.

Comment [PJT178]: SC#56

As discussed in Section 6, the distribution of mercury in site media (low presence in groundwater) and the sequential extraction results indicate that mercury at the site is adsorbed to site soils. The exception appears to be bedrock groundwater in the northwestern area of the site (wells MW-17D, MW-18D, and MW-20D). As detailed in Section 6.4.2.1, these wells contain groundwater impacted from the adjacent GAF site, which contains dissolved mercury. Mercury used by GAF is in a different form than the chlor alkali-derived mercury discharged at the LCP site.

Comment [PJT179]: SC#55

PCBs, PCNs, HCB, and PCDFs are highly insoluble and will exist adsorbed in the environment (e.g., adsorbed to soil particles). In addition, chlorobenzene adsorbs significantly (ATSDR, 1990, 1998). Benzene will also adsorb in soils and groundwater in the presence of significant organic matter (ATSDR, 2007). Total organic carbon (TOC) in site soils varies by unit, with the highest concentrations (averaging 7 percent) observed in the tidal marsh deposits. Fill is highly variable in TOC content, averaging pproximaftely 3 percent. Glacial till contains relatively little TOC (0.3 percent).

7.1.3 Solubilization

Mercury species vary widely in aqueous solubility. Most organomercurics are insoluble, with the exception of methylmercuric hydroxide (CH_3HgOH), which is highly soluble due to the strong hydrogen bonding capability of the hydroxide group. The mercuric salts vary widely in solubility. Mercuric chloride ($HgCl_2$) is readily soluble in water, while mercuric sulfide (HgS) is highly insoluble. Once mercury is in solution, adsorption/desorption reactions dominate (Renneberg and Dudas, 2001). Due to competition from chloride, which reduces mercury binding to humic substances, salinity enhances solubilization and therefore correlates with greater mercury mobility (Bollen at al, 2008).

The RI data indicate that the soluble portion of mercury in groundwater varies by location and stratigraphic unit. The most impacted well was overburden location MW-24S, in the center of the LCP site, which contained 233 µg/L total mercury (Figure 6-25a and 6-25b). The filtered sample from MW-24S was reported at 164 µg/L, indicating that more than half of the mercury in this well is dissolved. The Ditch Bridge Area material, near where MW-24S was screened, was substantially different than other subsurface areas of the site. The next most impacted well, MW-23S, contained 27 µg/L total mercury, a slightly lower proportion of which (7.9 µg/L) was reported as dissolved. All other filtered results for the overburden unit were less than 2 µg/L. ~~Bedrock mercury concentrations were all 11 µg/L or less. However, in the bedrock, dissolved and total mercury concentrations were virtually identical but~~

Comment [PJT180]: SC#57

~~the source of this mercury is from off site.~~ As discussed above and in Section 6.4.2.1, dissolved mercury in bedrock in the northwestern area of the site is from the adjacent GAF site and not from LCP Site chlor alkali-derived sources.

Surface water samples from South Branch Creek did not contain detectable soluble mercury.

HCB was only reported in one well above the standard of 0.02 µg/L (1 µg/L in MW-24S), indicating lack of soluble presence. PCNs were identified as TICs in soil but were not detected in groundwater. PCBs were not detected in groundwater. The CDDs/CDFs detected at trace concentrations in unfiltered groundwater are likely due to suspended solids, as these constituents are extremely insoluble in water.

Benzene and chlorobenzenes were reported in groundwater. These constituents have a higher solubility than other chemicals present in LCP site soils and therefore would be expected to partition to some extent into groundwater. In fact, as discussed in Section 6.4.3, these constituents are attributed to migration in the dissolved phase from the former NOPCO site. In addition, as discussed throughout the RIR, there are sources of off-site VOCs in the immediate site area, including GAF, NOPCP, and adjacent bulk petroleum storage facilities.

Comment [PJT181]: SC#54

7.1.4 Density-Driven Migration

Elemental mercury has a density more than 13 times that of water and negligible aqueous solubility (see Table 7-1). As a result, elemental mercury not transformed into other mercury species may have the potential to migrate vertically as a free phase in the subsurface. While there is some literature regarding the existence of mercury dense non-aqueous phase liquid (DNAPL) in the subsurface (USEPA, 2001), its formation and migration are apparently not well understood.

DNAPL is typically characterized by immiscibility with water (forms a separate phase), low absolute solubility (minimal dissolution in groundwater, hence high persistence), greater density than water (tendency to sink within the saturated zone), and low viscosity (facilitating subsurface migration). Classic DNAPL migration phenomena are well described in the literature and are generally based on the behavior of organic chemicals (e.g., chlorinated solvents) in the subsurface. Movement of DNAPL is governed primarily by capillary resistance and gravity (NAVFAC, 2004; Vuillamy, undated), with material moving along the path of least resistance. Although DNAPL typically tends to sink under the force of gravity, it may also exhibit upward migration as a result of capillary forces, even re-emerging at the surface.

~~Mercury has, in fact, been observed at the LCP site to pool on the ground and paved surfaces immediately after rainfall events.~~ Mercury has, in fact, been observed at the LCP site beaded on the surface or in small puddles on the ground and paved surfaces immediately after rainfall events and in association with mechanical disturbance of the soil. An evaluation of this phenomenon was made by Geosyntec (2006). It is well established that the physical characteristics of mercury, particularly surface tension, are far different than those of other fluids typically found in the subsurface, notably water and chlorinated solvents. Specifically, mercury has a notable lack of attraction for soil and pavement-material pore spaces (Aït-Mokhtar, *et al.*, 2004) that prevents it from migrating deeply into narrow pores. Therefore, mercury can actually be held back from downward migration under the force of gravity by its greater attraction of surface tension within the mercury itself. Mercury has a strong attraction to itself and will form discrete spherical beads rather than adhering to other materials.

Comment [PJT182]: SC#54

It is likely that the observed phenomenon of mercury pooling on the ground surface results from the interactions of surface tension and wetting properties of water and mercury in the subsurface materials. Mercury contained in the pore spaces has no “attachment” to the pores spaces but has simply moved downward under the force of gravity within relatively large pores to the lowest point that can support this migration. The mercury cannot wick through narrow pores such that it remains held up in wider pore spaces nearer the surface.

The entry of water into the pores after a precipitation event creates a new dynamic. Infiltrating water is highly attracted to the soil pores and is wicked downward into the subsurface. This wetting property force that draws the water into the small pores is actually greater than the force of gravity that allowed mercury to settle into the pore spaces. Therefore, the entry of water into the pores causes the mercury to lift out of the pore spaces which is subsequently replaced by the water. In summary, mercury appears to be lifted by a combination of surface tension, pore size, and the poor wetting properties of mercury (Geosyntec, 2006).

The RI data reveal that elemental mercury is present the subsurface at the LCP site. However, these data suggest that the distribution of mercury decreases with depth such that it is substantially attenuated upon reaching the natural soil units (i.e., tidal marsh deposits and glacial till) underlying the fill, with the exception of the area located immediately beneath the mercury cell buildings. Although counterintuitive considering of its very high density, there is little evidence that downward vertical migration of mercury occurs as a result of classic patterns of DNAPL migration.

7.1.5 Advection

Advection is the transport of a substance in a moving fluid. In most environmental systems, this process occurs in either groundwater or surface water. Adsorption limits the potential for advection by retaining contaminants.

Finely suspended material can be transported off-shore and is a principal mechanism of transport of sediment-bound mercury (Beldowski and Pempkowiak, 2007). The tidal cycle evaluation performed in South Branch Creek in February 2007 (see Section 6.5.1) demonstrated that mercury is only observed in the particulate-bound (vs. dissolved) form and its transport is associated with suspension during the tidal cycle. This pathway appears to represent the major sediment transport mechanism at the LCP site. Suspension-related transport, however, appears to have resulted in re-deposition over a relatively limited distance, since total mercury concentrations decline approaching the mouth of South Branch Creek, and the sediment samples collected in the transect just beyond the outlet of South Branch Creek to the Arthur Kill represent background conditions.

Within groundwater, mercury will migrate with flow if it is dissolved. Despite the presence of some soluble mercury in LCP site wells, the pattern of mercury in groundwater indicates that this process does not appear to be significant at the LCP site. The highest groundwater concentrations were observed in the central areas of the LCP site, with decreasing concentrations in the downgradient direction toward South Branch Creek and the unnamed tidal ditch that borders the LCP site to the south. Dissolved mercury was not detected in the overburden samples closest to surface water bodies, with the exception of MW-14S, which had a trace of mercury (0.39 µg/L, well below the groundwater standard of 2 µg/L). This pattern is consistent with studies that have shown that soluble mercury in groundwater decreases over distance due to complexation (transformation of the more soluble form $HgCl_2$; Bollen, *et al.*, 2008).

The pattern for VOCs in groundwater differs. Both benzene and chlorobenzene are present throughout overburden groundwater and show among the highest concentrations in wells adjacent to surface water. ~~In addition, while the concentrations between the overburden and the bedrock for these VOCs do attenuate overall, there is still considerable chlorobenzene presence in bedrock (up to 1,140 µg/L). Furthermore, the highest concentrations in bedrock do not correlate spatially with those in overburden, suggesting that the bedrock presence is accounted for at least in part by lateral migration within the bedrock unit.~~ The VOCs in bedrock groundwater do not correlate spatially with those in overburden and, furthermore, the pattern of benzene and chlorobenzene in bedrock groundwater is spatially related to the mercury and results from off-site sources at the adjacent GAF, NOPCO, or petroleum storage sites.

Comment [PJT183]: SC#54

7.1.6 Transformation

The environmental chemistry of mercury is complex. Mercury in aquatic systems is subject to methylation, forming methyl mercury (MeHg) compounds, predominately monomethylmercury. Methyl mercury is accumulated and retained by aquatic organisms. The biotransformation of inorganic mercury species to methylated organic species in water bodies can occur in both sediment and the water column. Abiotic processes (such as humic and fulvic acids in solution) can also facilitate methylation (USEPA, 1997). Lower pH may promote monomethylated over dimethylated forms (Hinton and Veiga, 2008).

Reduction of Hg^{+2} to elemental mercury is facilitated by humic matter in both aqueous and soil systems (Mauclair, *et al.*, 2008).

Elemental mercury is stable over a large range of environmental conditions (McComish and Ong, 1988). This property is consistent with the presence of a significant quantity of elemental mercury in LCP site soils, as indicated by the visual observations summarized on Table 6-3.

In water, mercury can be hydrolyzed and behave as an acid. Hg_2^{+2} is a weaker acid than Hg^{+2} (McComish and Ong, 1988). Other transformation processes in water include photolytic oxidation and reduction, abiotic oxidation and reduction, and complexation with anions such as chloride, hydroxide, sulfide (cinnabar formation), and dissolved organic carbon (Knightes, 2008). As discussed above, mercury has an affinity for organic matter in soil and will form organic complexes; it will also transform between inorganic and elemental forms.

PCBs (ATSDR, 2000) and HCB (ATSDR, 2002) are generally resistant to degradation and transformation in the environment. However, lower-chlorinated PCNs may be amenable to biodegradation, as evidenced by a lower proportion of the lower chlorinated PCNs than the higher-chlorinated congeners in some systems (Falandsyz, 1998). CDDs may be subject to photolysis, but are generally resistant to microbial degradation (ATSDR, 1998).

For benzene and chlorobenzenes in soil and water, biodegradation is a significant fate mechanism, especially under aerobic conditions (ATSDR, 1990, 2006, 2007). The extent to which chlorobenzenes may represent daughter products of higher-chlorinated species is unknown. A variety of chlorobenzenes were used by GAF (Eckenfelder, 1991) and NOPCO, so the mono-, di-, and tri-chlorobenzenes present may represent a combination of original chemicals and reductive degradation products.

7.1.7 Bioaccumulation

Mercury's tendency to bioaccumulate is a key characteristic and accounts for its environmental significance. Methylation is the primary mechanism of mercury entry into the food chain. Methyl mercury is very bioavailable and accumulates in fish through the aquatic food web. Essentially all of the mercury found in fish muscle tissue is in the methylated form (USEPA, 1997). Studies have shown the earthworms can bioaccumulate mercury in terrestrial systems. This process is strongly associated with the presence of organic acids. There is some evidence that mercury taken up from soils can be methylated in the invertebrate gut (Hinton and Veiga, 2008). Mercury has also been reported to accumulate in the wetland grass plants (*spartina*) after treatment with MeHg solution (Zhu, *et al.*, 2004).

Tables 6-46a and 6-46b present the estimated BSAFs for the inorganics in fish and crabs, respectively. These data were explored in Section 6.8. Overall, there is little evidence of biomagnification, with even mercury (the only inorganic expected to be bioaccumulative) demonstrating biota-sediment accumulation factors (BSAFs) well below 1. Correlation between sediments and tissue concentrations was generally poor.

Comment [PJT184]: SC#58

HCB and PCBs are both considered highly bioaccumulative. Along with mercury, they are among the 12 constituents classified by the USEPA as priority PBT (persistent, bioaccumulative and toxic) chemicals (USEPA, 2008b). For both PCBs (ATSDR, 2000) and PCNs (Helm, *et al.*, 2008; Falandysz, 1998),

increasing chlorination is strongly associated with the potential for bioaccumulation. Thus the mono- and di- PCN congeners identified at the LCP site present a lower bioaccumulation concern than would more highly chlorinated species. However, AR1254 and AR1260 are among the more bioaccumulative PCB species.

The only organic measured in tissue (other than organic arsenic species in fish) was PCBs. Given that PCBs were analyzed as Aroclors in sediments and as congeners in biota (per EPA's request), the estimation of bioaccumulation is not straightforward. For this reason, the BERA (see Appendix Q) relied on published estimates of PCB biota-sediment accumulation factors (BSAFs) in estimating food chain exposure.

Comment [PJT185]: SC#58

7.2 Factors Affecting Contaminant Migration

The principal factor affecting mercury migration is the species in which the mercury occurs. Mercury exists as three oxidation states in the environment: Hg^0 (elemental), +1 (Hg_2^{+2}), and +2 ($2(Hg^{+2})$). As indicated above, the elemental form can persist, although in reducing environments, highly insoluble HgS (cinnabar) precipitation is expected (McComish and Ong, 1988). The non-cinnabar fractions are primarily associated with mercury mobility and potential bioavailability (Kocman, *et al.*, 2004). Thus redox is a key factor controlling mercury speciation and therefore partitioning and migration.

A number of variables control the form of mercury, including the quantity of organic matter/sulfur-containing binding sites, soil solution chemistry, soil texture and mineralogy, ultraviolet light, and the presence of sulfate-reducing bacteria. Methylation in soils tends to be relatively low compared to sediments. However, aquatic systems and wetlands convert a small but significant proportion of mercury to the methylated form (USEPA, 1997). In groundwater, the occurrence and stability of mercury species depends on eH (oxidation reduction potential) and pH, with inorganic species dominating (Bollen, *et al.*, 2008). The pH also affects the degree of methylation, with acidic systems demonstrating greater bioaccumulation (Hinton and Veiga, 2008; USEPA, 1997). A variety of other variables also influence mercury speciation and behavior, including chloride (as discussed above), iron (Fe^{+3}), copper (Cu^{+2}; Hinton and Veiga, 2008), temperature (Bollen at al, 2008). Light has been shown to increase emission of mercury from surfaces (Mauclair, *et al.*, 2008).

Important factors influencing the bioavailability of methyl mercury to aquatic organisms include dissolved organic carbon (DOC) and solids, which complex methyl mercury and reduce the bioavailable pool. As a result, fish tissue concentrations are most strongly correlated with aqueous (rather than sediment) MeHg concentrations (Knightes, 2008). Bioconcentration factors (BCFs) from water to fish tissue have been reported as being in the 10^5 to 10^6 range for methyl mercury (USEPA, 1997), which is comparable to the 10^5 levels observed in South Branch Creek and the Arthur Kill. (see Section 6.8.1).

Complex organics with low aqueous solubility (PCBs, HCB, PCNs, and CDDs/CDFs) will be transported primarily adsorbed to particles in either air or water. Migration in soils would be expected to be minimal, except as run-off in particle-bound form. Migration in the aquatic environment will be largely a function of sediment deposition patterns.

7.3 Contaminant Persistence

Since mercury is an element, it cannot be degraded, only transformed. The principal mechanisms by which mercury would be expected to leave the site area would be volatilization, bioaccumulation, and sediment transport. However, the relatively elevated concentrations present and their marked clustering around historic sources areas suggest limited overall migration over time.

As indicated above, HCB, PCBs, and PCDFs are highly persistent due to resistance to degradation and high adsorption (ATSDR, 2000; 2002). Mono- and di-PCNs are less persistent and may degrade over

time. Both benzene and chlorobenzene have relatively short residence times in soil and water, and are not expected to partition significantly to sediments (USEPA, 2008).

7.4 Conceptual Site Model (CSM)

Contaminants associated with the site media fall into three general categories:

1. Contaminants associated with site operations: these include constituents directly resulting from the chlor-alkali processes (principally mercury, HCB, possibly PCNs and PCDFs), and those that were spilled or discharged as part of general facility operations (PCBs from electronic transformers, BTEX from fuel and lubricating oil);
2. Contaminants that are incidental as a result of placement of contaminated anthropogenic fill (benzene, chlorobenzenes, PAHs, most metals).
3. Background conditions due to atmospheric deposition, stormwater and other discharges from non-site sources, and sediment transport from the Arthur Kill (PCDDs/PCDFs, PAHs, most metals, and mercury, benzene, and chlorobenzene in bedrock groundwater).

Comment [PJT186]: Revised Section 7

Site-related contamination originated in the upland (manufacturing facility) area. During the period of chlor-alkali operation, mercury (the principal COC) was discharged to the environment atmospherically or to the ground through spills or disposal of waste. A widespread presence of mercury remains in soils, including visual evidence of elemental mercury. However, vertical migration of mercury in soils beneath the fill is relatively limited. The deeper fill itself contained far lower total mercury concentrations than the shallow fill, with only half as many exceedances of the applicable soil standard (Nonresidential Direct Contact Soil Standard, 65 mg/kg). Native material underlying the fill (tidal marsh deposits and the glacial till) contained mercury below the standard in more than ¾ of the samples, indicating further attenuation.

Relatively little mercury has partitioned into groundwater. ~~Only one filtered sample from the overburden exceeded the Alternative Groundwater Quality Criteria (AGWQC) of 24 µg/L~~ Only one filtered sample from the overburden exceeded the Groundwater Quality Standard (GWQS) of 2 µg/L, and dissolved mercury was undetected in most of the samples located between the production area and South Branch Creek. The higher concentrations of mercury in the unfiltered samples relative to filtered samples demonstrate that mercury is adsorbed onto solids and not generally present in the dissolved phase.

Comment [PJT187]: Revised Section 7

This pattern of mercury groundwater detections indicates that there is a general absence of lateral migration of mercury in overburden groundwater given the lack of laterally extensive plumes across the site. Discharging overburden groundwater to South Branch Creek is generally free of mercury contamination. Only three of the bedrock groundwater samples contained detectable mercury and those are related to an off-site source. These bedrock mercury detections were limited to the western portion of the site (in the opposite direction of the Arthur Kill, the receiving surface water body). Pumping from the adjacent GAF site, has been demonstrated to capture bedrock groundwater under the LCP site, including the area in which mercury was detected in bedrock groundwater. This phenomenon has been detailed in previous sections of this RIR (see, for example, Sections 5.2.3 and 6.4.2).

Comment [PJT188]: SC#59

These soil and groundwater observations are consistent with the presence of mercury in an insoluble form. The results of the sequential extraction analyses performed on soils confirm that the majority of mercury exists in site soils as the most insoluble species (primarily cinnabar and elemental mercury). For this reason, migration in the subsurface has been limited and further migration is not anticipated.

The mercury detected at high concentrations in South Branch Creek and the Northern Off-Site Ditch (both sediments and the near-creek low marsh soils, which reflect sediment deposition during tidal surges or storm events) is likely due to historic overland releases in which soil-bound mercury moved via advective flow into the nearest surface water body. The presence of elevated mercury in soils along the alignment of the historic South Branch Creek channel and the southern boundary of the LCP Site is

Comment [PJT189]: Ditch Report

Comment [PJT190]: Ditch Report

consistent with the overland release migration mechanism. Both uncontrolled stormwater run-off and piped discharges are likely to have contributed to transport. Mercury that was atmospherically deposited to near-facility surface soils would also have subsequently been transported via run-off. Subsequent tidal mixing and continuous suspension/redeposition may explain why clearer gradients with depth are not uniformly observed.

Changes in site drainage patterns after 1976 and the cessation of chlor-alkali manufacturing activities in 1985 would have dramatically decreased the quantity of overland releases to South Branch Creek after that time. Furthermore, as discussed in Section 2.6.1, the flat gradient at the site and lack of drainage structures provide for minimal ongoing stormwater discharge to South Branch Creek. There is some tendency for mercury to appear at the ground surface during rain events; however, elemental mercury is highly insoluble and should experience negligible entrainment given the minimal run-off overall from the site to South Branch Creek. Since groundwater is a negligible source of mercury to surface water, the transport of mercury to South Branch Creek can be considered historic.

Comment [PJT191]: SC#60

Mercury in South Branch Creek sediments and adjacent low marsh soils is present at the highest concentrations in the areas closest to the former manufacturing facility (Transect A) and in relation to the depositional nature of a "back-bay" area and the possible drainage inputs (e.g., infiltrated groundwater) from the large concrete pipe that drains at Transect C. The correlation of the existing pattern of mercury presence with historical inputs known to have ceased decades ago strongly indicates that outward mercury migration from the channel is now limited. The attenuation of mercury concentrations in sediments as South Branch Creek reaches the Arthur Kill provides further support for limited sediment transport, since extensive mixing over time would have reduced or eliminated the clear concentration gradient.

Drainage from the southern portion of the LCP site, adjacent to the Northern Off-Site Ditch has remained consistent throughout the operational history at the LCP plant. The spatial distribution of mercury found in the Northern Off-Site Ditch sediments is consistent with an overland migration of contaminants in stormwater runoff from the former Linde Hydrogn Plant area. Mercury, likely related to the chlorine gas purification process, was observed in fill material in the vicinity of the Linde Hydrogen Plant.

Comment [PJT192]: Ditch Report

~~Net transport of mercury via flow of suspended particulates in surface water also appear to be limited, as surface water concentrations are several orders of magnitude lower than sediments concentrations.~~ The migration of very low levels of mercury that suspend in surface water may be environmentally significant because mercury can be relevant in the environment at low concentrations. However, this pathway is unlikely to serve as a mechanism for moving or altering the bulk mass of mercury present in sediments.

Comment [PJT193]: SC#61

As discussed above in Section 7.1, there may be some solubilization, chemical transformation, and volatilization of the small amount of mercury that resides in the water column. Again, these processes affect a vanishingly small proportion of the mercury load in sediments and are not significant from a bulk transport perspective. However, as discussed in Section 6.5, the small amount (approximately 0.1 to 0.2 percent) of mercury in surface water that has become methylated is associated with methyl mercury bioconcentration factors (BCFs) from water to fish in the 10^5 range. Sediments are also likely contributing to biological accumulation, as evidenced by the elevated fiddler crab concentrations. Both fish and crabs serve as prey species that can contribute to mercury biomagnifications up the food chain. Therefore, while the significance of this pathway from a bulk transport perspective is unkown, movement from sediment into biota is an environmentally significant migration pathway. The proposed Interim Action (IA) would have terminated this transport pathway.

PCBs, PCNs, HCB, and PCDDs/PCDFs originating in soils adjacent to the former facility would be expected to behave in a similar manner as mercury, traveling primarily via run-off adsorbed onto solids. PCBs were generally low in South Branch Creek (undetected or at part-per-billion levels), but

demonstrated a similar pattern to mercury, with the highest concentrations at Transects A and C. PCBs were not detected in Arthur Kill sediments, indicating attenuation with distance from the site. HCB movement appears to have been minimal, as this compound was undetected in South Branch Creek samples except for one occurrence of 1.5 mg/kg in the 0.5-1.0-foot sediments at Transect C and two detections under 0.2 mg/kg in low marsh soils at Transect B (Tables 6-17 and 6-32 and Appendix J). HCB was also not detected in the Northern Off-Site Ditch.

Lower-chlorinated chlorobenzenes appear to have migrated to South Branch Creek and the Northern Off-Site Ditch via the same mechanism of adsorption/run-off. These constituents, which have higher solubility than the other COCs, have also partitioned into groundwater, as has benzene. A portion of what is observed in South Branch Creek and the Northern Off-Site Ditch may be attributable to the localized discharge of chlorobenzenes in shallow groundwater to the ditch from the MW-6 area. However, this mechanism is unlikely to account for more than a small proportion of what is observed in sediments. These more soluble COCs have relatively short residence times in surface water due to volatilization and their higher aqueous solubility results in less partitioning to sediment. Thus relatively little benzene and chlorobenzene is observed in sediment compared with the higher-chlorinated compounds, which are more likely to have migrated adsorbed to solids.

As discussed in Section 6, arsenic, PAHs, and metals other than mercury are not associated with site operations and their presence in soils is attributable to anthropogenic fill, regional contamination, or other historic sources to South Branch Creek. The markedly elevated arsenic noted in sediments (concentrations greater than the maximums detected in any of the soil units) appears to be related to a local source other than the LCP site. South Branch Creek received inputs from various other sources, including the duPont site, GAF, and NOPCO. In addition, the crab speciation data suggest that an unidentified complex organic form of arsenic may be present in the Transect A area.

Comment [PJT194]: Ditch Report

Comment [PJT195]: Ditch Report

Comment [PJT196]: Ditch Report

Section 8

Baseline Risk Assessment Summary

8.1 Human Health Risk Assessment

The Human Health Risk Assessment (HHRA) evaluated the potential exposure of human receptors to constituents detected in environmental media at the LCP Chemicals, Inc., Superfund Site. The objectives of the HHRA were to determine whether chemicals of potential concern (COPCs) present in environmental media as a result of historic releases at the site pose unacceptable risks to human health under current and reasonably anticipated future land use, and to provide information to support decisions concerning the need for remedial action. The full HHRA appears in Appendix P.

Comment [PJT197]: Section Re-written to match final HHRA and BERA

Human exposures to site media are currently limited since the site is unoccupied and not used for any operational purpose. The majority of the site is surrounded by perimeter fencing and secured gates. Therefore, exposure to soil, shallow groundwater and indoor air (via vapor intrusion) under current conditions are incomplete exposure pathways. Cancer risks for future hypothetical construction workers via dermal contact with groundwater exceeded the low end of USEPA acceptable risk levels due to polychlorinated dibenzo furans (PCDFs). Future use potential non cancer risk estimates to site occupants for direct exposure to soil and inhalation of vapors in indoor air exceeded the USEPA benchmark due primarily to mercury. All other cancer and non cancer risks were within acceptable levels.

Exposures and risks were evaluated for the receptor groups described below.

Future commercial industrial workers: This receptor group represents a potential full-time site occupant who may be exposed to surface soil via incidental ingestion, dermal contact, and inhalation of dust and particulates. Excess lifetime carcinogenic risks under both the CT and RME scenarios were within the acceptable risk range of 10^{-4} to 10^{-6}. The hazard index (HI) representing noncarcinogenic hazard was somewhat above the benchmark of 1 for the RME scenario (7.5) and borderline for the CT scenario (1.5). The hazards are driven almost entirely by inhalation of elemental mercury. Based on the Adult Lead Model, concentrations of lead in soil are not expected to result in adverse health effects.

Future site workers: This receptor group is based on an anticipated site use as a trucking depot/parking facility and assumes the same exposure routes as a commercial worker but to a more limited extent than for future commercial industrial workers. Carcinogenic risks under the RME scenario were within the acceptable risk range and CT risks were below a level of concern. The HI was somewhat above the benchmark of 1 for the RME scenario (6.1) and borderline for the CT scenario (1.6). The hazards are driven primarily by inhalation of elemental mercury. Concentrations of lead were not predicted to results in adverse health effects.

Future construction workers: Construction workers may be exposed to surface and subsurface soil and shallow groundwater during intrusive activities. Carcinogenic risks under both the CT and RME scenarios were within the acceptable risk range of 10^{-4} to 10^{-6}. The HIs under both the RME (23) and CT (8.2) scenarios were above the benchmark. The major drivers were dermal contact with PCDFs in groundwater; secondary contributors were dermal contact with manganese in groundwater, and inhalation and ingestion of mercury in soils. Concentrations of lead were not predicted to results in adverse health effects.

~~**Future indoor workers:** Future building occupants may be exposed to indoor air impacted by soil vapor containing mercury and VOCs volatizing into buildings. Modeled concentrations of mercury and VOCs exceed health based criteria for industrial/commercial receptors. Risks are driven by exposure to elemental mercury and to a lesser extent by hexachlorobutadiene, chloroform, carbon tetrachloride, and PCE.~~

~~**Trespassers:** A trespasser, assumed to be an adolescent who comes into contact with sediments in South Branch Creek, was evaluated, although tidal influence and a lack of attractive nuisances generally preclude human exposure to South Branch Creek via Arthur Kill. Risks and hazards to trespassers under both CT and RME assumptions were within acceptable limits.~~

~~Areas of visible elemental mercury contamination could not be quantitatively evaluated. For the purposes of the baseline risk assessment, areas with visible elemental mercury were assumed to present an unacceptable risk for future commercial/industrial, site specific workers, and construction workers based on potential direct contact and vapor intrusion pathways.~~

~~The HHRA supports the following conclusions:~~

- ~~Future use potential cumulative cancer risks to future commercial/industrial, site specific, and construction workers were within USEPA acceptable risk levels.~~
- ~~Future use potential non cancer hazards to workers exceeded the USEPA benchmark value of 1, primarily due to inhalation of elemental mercury and the ingestion of inorganic mercury.~~
- ~~Cancer and noncancer risks to trespassers are within USEPA acceptable risk levels.~~
- ~~Exposures to areas containing visible mercury are assumed to present unacceptable risks.~~

~~Several of the chemicals that contributed to the risk estimates are believed to be associated with the fill present at the Site or are found in regional soils. These constituents include arsenic, some metals, and PCDFs. Other chemicals, such as hexachlorobutadiene and VOCs, are found at elevated concentrations in only a few locations, indicating that risks associated with these compounds are localized in nature.~~

The human health risk assessment (HHRA) evaluated potential exposure of human receptors to constituents in environmental media at the Site under current conditions (i.e., unremediated conditions). Consistent with standard risk assessment practice and USEPA guidance, the HHRA included the following elements: data evaluation and selection of chemicals of potential concern (COPCs); exposure assessment; toxicity assessment; and risk characterization. The full HHRA is provided as Appendix P.

The objectives of the HHRA were to determine whether COPCs present in environmental media as a result of historic releases at the Site pose unacceptable risks to human receptors and to provide information to support decisions concerning the need for further evaluation or action at the Site, based upon current and reasonably anticipated future land use. Receptors and exposure pathways identified for quantitative and qualitative evaluation in the HHRA, and the rationale for their selection, are described below.

- **Future commercial/industrial workers.** Based on existing and reasonably foreseeable land and water uses, future commercial/industrial workers are the most likely human receptors at the Site. Future commercial/industrial workers were assumed to be potentially exposed to COPCs in surface soil via incidental ingestion, dermal contact, and inhalation of vapors and particulates in ambient air; and volatile COPCs in indoor air via inhalation. Despite the unlikely use of groundwater for potable or other purposes, it was assumed that future commercial/industrial workers could ingest overburden groundwater at the Site. (Note: this pathway is not reasonably anticipated, but is included to provide risk managers with information needed to evaluate the impact of any future changes in groundwater use at the Site.)

- **Future site-specific workers.** In addition to a full-time commercial/industrial worker scenario, a reduced-frequency commercial/industrial ("site-specific") worker was also evaluated. This scenario is based on potential redevelopment of the Site as a truck depot (parking lot). Under this scenario, workers were not anticipated to be present at the Site on a full-time basis. Although this scenario is hypothetical, and it is acknowledged that such future land use would require institutional controls, the evaluation of this receptor supports remedial decision-making and the risk management process. Future site-specific workers were assumed to be potentially exposed to COPCs in surface soil via incidental ingestion, dermal contact, and inhalation of vapors and particulates in ambient air.
- **Future construction/utility workers.** Future on-site construction/utility workers were assumed to perform short-duration construction related to future redevelopment of the Site or maintenance. Future construction/utility workers were assumed to be potentially exposed to COPCs in surface and subsurface soil via ingestion, dermal contact, and inhalation of vapors and particulates in ambient air. Future construction/utility workers were also assumed to be potentially exposed to COPCs in shallow (overburden) groundwater via dermal contact. Incidental ingestion of groundwater and inhalation of vapors by construction/utility workers are qualitatively evaluated in the uncertainty assessment.
- **Current/future trespassers.** Trespassing, although unlikely due to perimeter fencing, nearby security, and the isolated location of the Site away from residential areas, could potentially occur at the Site. Current/future trespassers were assumed to be potentially exposed to COPCs in sediment/bank soil of South Branch Creek via incidental ingestion and dermal contact. Trespasser exposure to surface water in South Branch Creek was qualitatively evaluated.

Central tendency exposure (CTE) and upper-bound exposure (reasonable maximum exposure or RME) exposure estimates were selected for each receptor to quantify COPC intake. CTE estimates are intended to represent average, or typical, exposure to environmental media whereas RME estimates represent exposures that are greater than average, but still within a realistic range given Site conditions. While intake parameters varied between the RME and CTE scenarios, exposure point concentrations (EPCs) remained constant; EPCs are the 95% upper confidence limit on the mean (UCL) or maximum concentration. Note that EPCs did not account for visible elemental mercury as it was not possible to analyze these samples using conventional methods; however, it is assumed that areas with visible elemental mercury pose unacceptable risks to potential on-site receptors.

The risk characterization integrated exposure information for current and future human receptors with toxicological data to yield quantitative estimates of theoretical excess lifetime cancer risks and non-cancer hazard indices (HIs) for COPCs. The USEPA recognizes a generally acceptable cumulative excess cancer risk range between one-in-one million and one-in-ten thousand ($1x10^{-6}$ to $1x10^{-4}$) and an acceptable HI of 1 or less for groups of chemicals that affect the same target organ (USEPA, 1989). Potential risks associated with lead-impacted media were evaluated using the Adult Lead Model (USEPA, 1996).

The results of the HHRA support the following conclusions.

- Areas of visible elemental mercury contamination could not be quantitatively evaluated. For the purposes of the baseline HHRA, areas with visible elemental mercury were assumed to present an unacceptable risk for future commercial/industrial, site-specific, and construction/utility workers based on potential direct contact and vapor intrusion pathways. Risks attributed to these areas were based on current Site conditions (i.e., unremediated conditions).
- For current exposure conditions, the Site is unoccupied and not used for any operational purposes. Moreover, the Site is within the Tremley Point industrial area with a majority of the Site surrounded by perimeter fencing and secured gates. Thus, exposure to soil under current Site conditions is considered an incomplete exposure pathway. Likewise, there are no occupied buildings or complete

indoor air exposure pathways on-site. Currently, groundwater at the Site is not used for potable or other purposes.

- Future use potential cumulative cancer risks resulting from exposure to soil via ingestion, dermal contact, and inhalation of vapors and particulates were within USEPA acceptable risk levels for future commercial/industrial, construction/utility, and site-specific workers under a CTE scenario; however, future use potential cumulative cancer risks resulting from exposure to soil exceeded USEPA acceptable risk levels for future commercial/industrial workers under an RME scenario. Hexachlorobenzene, carcinogenic PAHs, furans, PCBs, and arsenic made the most significant contribution to overall cancer risk.
- Future use potential non-cancer risk estimates for direct exposure to soil via ingestion, dermal contact, and inhalation of vapors and particulates exceeded the benchmark value of 1 for future commercial/industrial, site-specific, and construction/utility workers under both RME and CTE exposure scenarios. The inhalation of elemental mercury and the ingestion of inorganic mercury made the most significant contributions to overall non-cancer risk.
- Future use of groundwater is unlikely due to the salinity and because two New Jersey regulations prohibit the installation of wells. However, because the overburden water-bearing zone is classified as Class II-A (potable), commercial/industrial worker ingestion of groundwater was quantitatively assessed to provide risk managers with information needed to evaluate the impact of any future changes in groundwater use at the Site. Cancer risks exceeded USEPA acceptable risk levels and non-cancer risks (HIs) exceeded the benchmark value of 1 for this hypothetical potable use scenario.
- Future construction/utility worker potential cumulative cancer risks resulting from exposure to groundwater via dermal contact were within USEPA acceptable risk levels; however, cumulative non-cancer risks exceeded the benchmark value of 1 for this receptor-exposure scenario. The groundwater ingestion and inhalation exposure pathways were not quantitatively evaluated; however, the dermal evaluation is sufficient to conclude that there is a potential for unacceptable risks (primarily non-cancer risks) associated with construction/utility worker exposure to groundwater.
- Based on the Adult Lead Model for future Site use, concentrations of lead in soil are not expected to result in adverse health effects to future commercial/industrial worker or site-specific workers exposed to surface soil, future construction/utility workers exposed to mixed soil, or trespassers exposed to sediment/bank soil in South Branch Creek.
- Soil vapor containing mercury and VOCs may volatize into buildings that may be constructed at the Site in the future. Under future use conditions, indoor air exposure pathways may be present with concentrations of mercury and VOCs that exceed health based criteria for industrial/commercial receptors. Risks are driven by exposure to elemental mercury and to a lesser extent by hexachlorobutadiene and chloroform.
- Although tidal influence and a lack of attractive nuisances generally preclude human exposure to South Branch Creek via Arthur Kill, trespassers may come into contact with COPCs in sediment/bank soils in South Branch Creek. Potential cancer and non-cancer risks estimates for current/future adolescent trespassers exposed to sediment in South Branch Creek were within USEPA acceptable risk levels.

In summary, the HHRA indicated that direct exposure to soil by future commercial/industrial workers, site-specific workers, and construction/utility workers may result in adverse non-cancer effects; exposure to soil by future commercial/industrial workers may also result in adverse cancer effects. Dermal contact with groundwater by construction/utility workers has the potential to result in adverse non-cancer effects. Potential non-cancer hazards in soil and soil vapor were driven by mercury; potential non-cancer hazards in groundwater were driven by furans and manganese. With the exception of future

commercial/ industrial exposure to soil, estimated excess cancer risks for these scenarios were within the USEPA risk range of $1.0x10^{-6}$ to $1.0x10^{-4}$. No unacceptable cancer or non-cancer risks were identified for current/future trespassers exposed to sediment/bank soil in South Branch Creek. Hypothetical use of groundwater for potable purposes was also evaluated to support remedial decision-making and risk management; the HHRA indicated future potable use of groundwater by commercial/industrial workers may result in adverse cancer and non-cancer effects.

Several of the chemicals that contributed to the risk estimates are believed to be associated with the fill present at the Site or are found in regional soils. These chemicals include the metals such as arsenic and dioxin/furan compounds. Other chemicals such as hexachlorobutadiene and VOCs are found in elevated concentrations in only a few locations indicating that risks associated with these compounds are localized in nature.

8.2 Ecological Risk Assessment

~~The following ecological exposure pathways were determined to be complete and were evaluated in the Baseline Ecological Risk assessment (BERA). Current conditions do not provide an attractive habitat for a wide variety of receptors. However, risks were developed for receptors that could inhabit the site in the future. Contaminants of potential ecological concern (COPECs) for specific site media were previously identified in the Problem Formulation phase of the ERA.~~

~~Exposure to animals was assumed to occur via the ingestion of contaminated prey items and due to incidental ingestion of substrate while feeding and grooming:~~

- ~~Exposure of benthic macroinvertebrates to contaminated sediment/bank soil in South Branch Creek.~~
- ~~Exposure of omnivorous mammals to contaminated sediment/bank soil, surface water, and prey items along South Branch Creek.~~
- ~~Exposure of piscivorous birds to contaminated sediment/bank soil, surface water, and prey items along South Branch Creek.~~

~~**Benthic invertebrates:** Several COPECs in South Branch Creek sediment have the potential to result in adverse ecological effects to benthic macroinvertebrates as determined by comparison to a range of marine sediment screening levels identified in the literature. Mercury is the primary driver, followed by arsenic, barium, chromium, zinc and PCBs. Acute sediment toxicity testing results from one sample of South Branch Creek sediments also indicated a potential for reduced benthic invertebrate survival.~~

- ~~**Omnivorous mammals along South Branch Creek:** Risks were estimated using measured fish and crab concentrations in a food chain model. Both CT and RME scenarios were evaluated, as were hazards based on both lowest observed adverse effect levels (LOAELS) and no observed adverse effect levels (NOAELS). HQs for raccoons assumed to be eating aquatic life from South Branch Creek were in the acceptable range, ranging from 0.2 to 1.~~
- ~~**Piscivorous birds along South Branch Creek:** Risks were estimated using measured fish and crab concentrations in a food chain model. Hazards to great blue heron were in the borderline acceptable range, ranging from 1 to 11. Hazards were driven by exposure to mercury and methyl mercury in diet.~~
- ~~**Insectivorous mammals (upland soil):** Risks were estimated using a food chain model that estimated uptake into invertebrate prey. Hazard quotients (HQs) for the short tailed shrew ranged from 25 to 400, indicating potential for hazard should this pathway exist. Drivers were antimony, cadmium, lead, mercury, hexachlorobenzene, PCBs, and TCE. However, ecological exposure to terrestrial soil is not considered a significant pathway given the limited habitat.~~

~~The BERA supports the following conclusions:~~

- ~~Ecological risks for upper trophic level receptors (raccoons and great blue herons) exposed to COPECs in South Branch Creek were generally below established risk benchmarks (of 1). However, there is a potential for limited ecological risk for the great blue heron.~~
- ~~Several COPECs in upland soil have the potential to result in adverse ecological effects to mammalian insectivores. However, ecological exposure to terrestrial soil is not considered a significant pathway given the highly disturbed habitat, lack of prey species and vegetation, and limited accessible soil due to buildings, pavement and gravel on site.~~
- ~~Elevated risks are predicted for benthic invertebrates in South Branch Creek.~~

~~Principal ecological concerns are for sediments in South Branch Creek.~~

The Ecological Risk Assessment (ERA) evaluated the likelihood that adverse ecological effects are occurring or may potentially occur as a result of the site-specific constituent concentrations remaining from historic site-related activities. As a baseline assessment, the ERA was intended to conservatively characterize ecological risk based on potential ecological exposure to environmental media under current conditions (i.e., unremediated conditions).

The ERA was performed in accordance with the USEPA (1997) *Ecological Risk Assessment Guidance for Superfund* eight-step paradigm. The Screening Level Ecological Risk Assessment (SLERA) was submitted by CDM to the USEPA on May 11, 2004. The SLERA indicated a potential for adverse ecological effects and a more thorough study in a Baseline Ecological Risk Assessment (BERA) was recommended. The full BERA is provided as Appendix Q.

Per the Problem Formulation Step[10], the BERA evaluated potential exposure of ecological receptors to constituents of potential ecological concern (COPECs) in environmental media in South Branch Creek and in the upland area. The potential for ecological exposure associated with each of these exposure areas is described below.

- **South Branch Creek.** The creek is partially rip-rap lined and due to the industrial nature of the area, represents impaired habitat; however, the creek functions as part of a larger tidal system. There is a layer of sediment on the bottom of the creek that supports a benthic community as evidenced by observed shells found around the creek bed during the Site visit (Brown and Caldwell, 2006). Prey species, including small estuarine fish and crabs, are present in the creek; thus, the potential for food chain exposure exists. Since the Site is located within the Atlantic Coast migration corridor, land and water birds could potentially use the creek; however, the Site does not provide sufficient habitat to support populations of birds. No aquatic mammals were observed at the Site; however, opportunistic mammals may forage along the creek. Based on these considerations, piscivorous birds and omnivorous mammals represent the most likely wildlife receptors at South Branch Creek. However, other wildlife receptors have also been evaluated at the request of USEPA.
- **Upland/Terrestrial Area.** The majority of the upland area is covered by asphalt pavement and packed gravel, and deteriorating buildings that offer marginal habitat for terrestrial wildlife populations. The Site may serve as a wildlife corridor for terrestrial species; however, the relative absence of vegetation indicates that a terrestrial food chain is limited. The results of the SLERA did not identify terrestrial food-chain impacts to predatory species as a primary concern at the Site. However, in order to address agency concerns regarding the upland area of the Site and as point-of-departure for making risk management decisions at the Site, several (unconfirmed) exposure pathways were also evaluated in the BERA.

[10] The Problem Formulation presented in the BERA is based on the draft Problem Formulation document prepared by Brown and Caldwell (2006) as well as subsequent discussions with agencies and agency comments on the Draft BERA, which was submitted by Geosyntec to the USEPA in September 2008.

Based on the rationale provide above, the BERA evaluated the following potentially complete receptor-exposure pathways (and representative receptors):

- Exposure of benthic macroinvertebrates to contaminated sediment/bank soil in South Branch Creek;
- Exposure of estuarine fish to contaminated sediment and surface water in South Branch Creek;
- Exposure of omnivorous mammals (raccoon; Procyon lotor) to contaminated sediment/bank soil, surface water, and prey items in South Branch Creek;
- Exposure of piscivorous mammals (mink; Mustela vison) to contaminated sediment/bank soil, surface water, and prey items in South Branch Creek;
- Exposure of sediment-probing birds (spotted sandpiper; Actitis macularia) to contaminated sediment/bank soil, surface water, and prey items in South Branch Creek;
- Exposure of piscivorous birds (great blue heron; Ardea herodias) to contaminated sediment/bank soil, surface water, and prey items in South Branch Creek;
- Exposure of invertivorous mammals (short-tailed shrew; Blarina brevicauda) to contaminated soil and prey items in the upland area of the Site;
- Exposure of carnivorous mammals (red fox; Vulpes vulpes) to contaminated soil and prey items in the upland area of the Site;
- Exposure of invertivorous birds (American woodcock; Scolopax minor) to contaminated soil and prey items in the upland area of the Site; and
- Exposure of carnivorous birds (red-tailed hawk; Buteo jamaicensis) to contaminated soil and prey items in the upland area of the Site.

Potential risks to benthic macroinvertebrate communities were primarily evaluated by comparing sediment COPEC concentrations in South Branch Creek to sediment benchmarks; additionally, bulk sediment toxicity testing was performed for lethality and growth (acute toxicity tests). Potential risks to estuarine fish communities in South Branch Creek were evaluated by comparing fish tissue COPEC concentrations to tissue toxicity reference values (TRVs). Potential risks to populations of upper trophic level (wildlife) receptors at the Site were evaluated using food chain models to calculate dietary doses, which were compared to dietary TRVs to yield a quantitative estimate of risk (hazard quotient [HQ]). An HQ of approximately 1 is generally regarded as having a low probability in resulting in adverse effects.

Two exposure levels were considered for evaluating potential ecological risks. The RME scenario considered exposure to upper-bound EPC estimates (95% UCL or maximum concentrations) and the CTE scenario considered mean concentrations. Note that EPCs did not account for visible elemental mercury as it was not possible to analyze these samples using conventional methods; however, it is assumed that areas with visible elemental mercury pose unacceptable risks to potential ecological receptors. If available, multiple effects levels were also considered. A range of screening levels and tissue TRVs that correspond to various effects were considered for benthic macroinvertebrates and estuarine fish, respectively. For wildlife receptors, both 'no observable adverse effect level' (NOAEL) and 'lowest observed adverse effect level' (LOAEL) TRVs were considered.

The results of the BERA support the following conclusions:

- Several COPECs in South Branch Creek sediment have the potential to result in adverse ecological effects to benthic macroinvertebrates as determined by comparison to marine sediment screening levels. Arsenic, barium, mercury, and methyl mercury are expected to be the primary risk drivers. South Branch Creek sediment acute toxicity testing results also indicated a potential for reduced benthic invertebrate survival.

- Fish tissue concentrations measured in South Branch Creek were within the range of tissue TRVs identified in the primary literature, indicating that South Branch Creek COPECs are not bioaccumulating to a level likely to adversely affect populations of estuarine fish.
- Ecological risks for omnivorous mammals (raccoons), piscivorous mammals (mink), and piscivorous birds (great blue herons) exposed to COPECs in South Branch Creek were below established risk levels. However, there is a potential for ecological risk to sediment-probing birds (spotted sandpiper) exposed to COPECs in South Branch Creek. Primary risk drivers are arsenic, barium, and mercury.
- Areas of visible elemental mercury contamination in the upland area of the Site could not be quantitivavely evaluated. For the purposes of the BERA, areas with visible elemental mercury were assumed to present unacceptable risk for potential ecological receptors. Risks attributed to these areas are based on current Site conditions (i.e., unremediated conditions).
- No unacceptable risks were identified for carnivorous mammals (red foxes) exposed to COPECs in the upland area of the Site. There is a potential for ecological risk to invertivorous mammals (short-tailed shrews), invertivorous birds (American woodcocks), and carnivorous birds (red-tailed hawks). Although the Site may serve as a wildlife corridor for terrestrial species, significant ecological exposure to soil is not expected to occur given the highly disturbed habitat, lack of prey species and vegetation, limited exposure potential due to buildings, pavement and gravel on Site, and anticipated future land use. Based on calculated risk estimates, primary risk drivers in the upland area are mercury and hexachlorobenzene.

In summary, elevated HQ risks were estimated in the BERA for benthic invertebrates and sediment-probing birds for exposure to several COPECs in South Branch Creek. These risks are consistent with the reduced survival in the acute toxicity sediment testing results. These data support the premise that Site contaminants in sediment are sufficient to cause adverse alterations to the functioning of benthic invertebrate communities. Elevated concentrations of the COPECs are generally higher in samples closer to the former facility. Arsenic, barium, and mercury are the primary risk drivers in South Branch Creek.

Elevated HQ risks were estimated in this BERA for terrestrial mammals (invertivores) and birds (invertivores and, to a lesser extent, carnivores). Primary risk drivers are mercury (including visible elemental mercury) and hexachlorobenzene. However, the former facility offers limited ecological habitat for these receptors as the majority of the Site is paved or occupied by structures. Concentrations tend to be focused in areas nearby the former operational areas of the Site. It is likely that remedial actions to address primary human health risk-drivers at the Site in these areas will also tend to reduce overall potential ecological risks for terrestrial receptors. However, residual ecological risks will be addressed in the FS.

Section 9

Conclusions and Recommendations

The RI field investigation was performed in two phases under the regulatory and technical oversight of the USEPA from 2001 through 2008. The RI report includes a comprehensive characterization of the nature and extent of contamination on the site in addition to assessments of risk to human health and the environment.

9.1 Site History

The LCP site is a former chemical manufacturing plant located on an approximate 26 acre property. The site was developed in the early 1950s for the production of chlorine by the brine-cell process (mercury cathode-carbon anode) also known as the chlor-alkali process. Chlorine manufacturing operations commenced in 1955 and continued until the plant was shut down in 1985. Related operations, including a hydrogen gas processing plant and sodium hypochlorite manufacturing area were also located on the site. While the plant was initially developed and operated by GAF beginning in 1955, the facility was sold to LCP in 1972 and was expanded and operated by LCP until 1985. Activities continued on site (by LCP and others) until 1994.

Hanlin Group, Inc., d.b.a. as LCP, filed a petition under Chapter 11 of the bankruptcy code in 1991 and liquidated all of its assets before April 1994 using the proceeds to pay creditors including the USEPA. The Linden, New Jersey property was abandoned by Hanlin Group pursuant to an order of the Bankruptcy court and ownership reverted back from the bankruptcy estate. Title to the property currently is listed as LCP-Chemicals New Jersey, a d.b.a. for Hanlin. Hanlin is a defunct corporate entity. The facility has remained abandoned since 2000.

The site was placed onto the National Priority List (NPL) in 1998. A voluntary Administrative Order was entered into by the USEPA and ISP Environmental Services Inc. (ISP-ESI) in 1999 to perform a Remedial Investigation and Feasibility Study (RI/FS). ISP-ESI is currently the only potentially responsible party, among several, that has cooperated with USEPA to address the site.

The LCP site has a complex history of property ownership. The north-central and eastern portions of the property were owned and developed by various companies preceding GAF dating back to the 1880s. Other portions of the property were previously owned by E.I. duPont de Nemours and Central Railroad of New Jersey (now Conrail).

The entire area of the LCP site and nearly all of the surrounding area was formerly tidal wetlands. It was necessary to raise the elevation prior to the historic development of these areas for industrial and other uses through the placement of anthropogenic ~~historic~~ fill. The filling of the wetlands occurred during the prior ownership of the property, before the development of the LCP site in 1955. ~~The anthropogenic fill found on the LCP site meets the legal definition of "Historic Fill" contained in the New Jersey "Technical Requirements for Site Remediation" [N.J.A.C. 7:26E].~~

Comment [PJT198]: ES#1

Comment [PJT199]: ES#1

The site has been zoned for "heavy industrial use" and continues as such as do the surrounding properties. It is anticipated that the upland portion of the site could possibly be re-developed into another industrial use, such as warehousing, transportation or electric power generation.

9.2 Contamination Sources

The RI results are summarized by the finding of the widespread presence of mercury in various environmental media as a result of manufacturing activities at the LCP site. Other potentially chlorine production-related contaminants are also found, including hexachlorobenzene (HCB), polychlorinated naphthalenes (PCNs), and polychlorinated dibenzo furans (PCDFs), although all at levels much less than those of mercury. Polychlorinated biphenyls (PCBs) are also a site-related constituent due their potential presence in electrical equipment on the site. Each of these other site-related constituents is present at levels much less than those of mercury.

Contamination is also present as a result of the prior placement of ~~historic~~ anthropogenic fill materials. Contaminants that are ubiquitous in fill materials include metals/metalloids (e.g., lead, chromium, and arsenic), and polycyclic aromatic hydrocarbons (PAHs) as a result of the common practice of using combustion residues (e.g., coal ash and slag) as fill. Other contaminants in the ~~historic~~ anthropogenic fill are consistent with sources of industrial fill from neighboring properties (e.g., duPont, GAF) and include arsenic and chlorobenzenes. Other various chemicals, including dioxins and lead, are also found from regional sources such as air deposition and sediment transport.

Comment [PJT200]: ES#1

Comment [PJT201]: ES#1

9.3 RI Field Investigation

The RI field investigation was performed in two phases. Phase I was performed in 2001 and 2002 and Phase II was performed from 2006 through 2008. The field investigations included hydrogeologic characterization, comprehensive sampling and laboratory testing of site media, and other related studies.

Hydrogeologic characterization of the LCP site was performed through the installation and testing of 26 shallow (overburden) and 11 bedrock monitoring wells. In addition, numerous deep soil borings were drilled for stratigraphic evaluation. Other hydrogeologic field testing was performed that included in-situ hydraulic conductivity tests, water level measurements, and tidal influence gauging.

A comprehensive program of sample collection and laboratory analysis of various site media was performed that included soils, soil vapor, groundwater, sediment, surface water, and biota. Approximately 400 soil samples were collected either as surficial samples or subsurface samples from one of the underlying overburden soil units including; the anthropogenic fill, tidal marsh deposits, and glacial till. Soil vapor samples were collected from the thin vadose zone in various areas of the site. Comprehensive rounds of groundwater quality samples were collected during each of the two phases from the wells available during each respective phase. Approximately 80 samples were collected from the low marsh soils and from multiple-depths from the sediments at seven (7) transects within South Branch Creek and the immediately adjacent portion of the Arthur Kill. Surface water samples and 18 biological tissue (fiddler crab and mummichog) samples were collected from the transect locations within South Branch Creek and the Arthur Kill. Field and laboratory QA/QC samples were also collected in addition to the investigative samples described above, including field blanks, trip blanks, field duplicates, MS/MSD samples, etc.

Laboratory testing of most samples from each medium, except biological tissue, included the Target Compound List (TCL) organic constituents and the Target Analyte List (TAL) inorganic constituents plus other indicator constituents appropriate to each medium. In addition, selected samples from each medium were tested for PCDDs/PCDFs and methyl mercury. Select soil samples were subjected to sequential extraction mercury analyses and Toxicity Characteristic Leaching Procedure (TCLP). One sediment sample was subjected to sediment toxicity testing. Biota samples were subjected to analysis for select metals and co-planer PCBs. Formal, third-party validation was performed on the chemical laboratory test data.

A separate investigation of surface water and sediments was conducted in the two Off-Site Ditches located adjacent to the southern boundary of the LCP Site. The investigation was conducted in August 2011, and included the collection of samples along three transects in each ditch and analyzed for the TCL and TAL constituent lists. Estimates of sediment thickness, ditch width, and water volumes of the two ditches were also generated.

Comment [PJT202]: Ditch Report

Several other studies were performed as part of the RI field investigation, including an ecological habitat assessment and a wetland delineation. A reference creek was selected from which samples of sediment, surface water, and biota were collected and tested for comparison of site data to regional conditions within the Arthur Kill basin. A professional land surveyor provided a photogrammetric base map which has been used for site mapping and also as-built surveys of the sample and well locations. Finally, a relational database and geographic information system (GIS) database was developed to manage and report the data.

9.4 Site Setting

9.4.1 Hydrogeologic Conditions

The geologic conditions underlying the site include overburden soil with a total thickness ranging from approximately 30 to 50 feet. The overburden overlies the red-brown shales and siltstones of the Passaic formation. The overburden at the LCP site consists of three stratigraphic units:

- Anthropogenic fill that continuously overlies the site with a range of thickness of 0.7 to 17 feet, and an average thickness of approximately 9 feet.
- Marine tidal marsh deposits ranging in thickness from 5 to 10.5 feet. The unit has been subdivided into two subunits, including a peat layer and an organic silt and clay layer.
- Glacial till ranging in thickness from 18.5 to 20.5 feet.

Three, distinct, laterally continuous hydrostratigraphic zones exist at the site, including:

- The uppermost water-bearing zone contained within the Fill and the Peat subunit of the Tidal Marsh deposits, termed the “overburden water-bearing zone”.
- An aquitard consisting of the organic silt & clay subunit of the tidal marsh deposits (where present) and the Glacial Till.
- The aquifer contained within the upper portion of the Passaic Formation bedrock, termed the “bedrock water-bearing zone”.

The shallow (overburden) water table configuration flows toward and discharges to the nearby surface water bodies including South Branch Creek and the Off-Site Ditches located immediately south of the site. A water table mound is evident in the center of the site, located between the two ditches. A regionally extensive aquifer exists within the competent bedrock portion of the Passaic formation bedrock that flows regionally east towards the Arthur Kill, its ultimate point of discharge. This pattern of bedrock groundwater flow is confirmed by the measurements made in the bedrock monitoring wells on the LCP site.

Comment [PJT203]: Ditch Report

Pumping from the bedrock water-bearing zone, as part of the groundwater remediation at the adjacent GAF site, creates a reversal of groundwater flow and provides bedrock groundwater capture for nearly the entire LCP site. Strong downward vertical hydraulic gradients exist from the overburden water-bearing zones to the underlying bedrock water-bearing zone in the entire site except for limited areas immediately adjacent to and beneath the site ditches. This downward gradient is present under both pumping and non-pumping conditions.

Due to the proximity of the Arthur Kill and other tidal waters to Linden, groundwater within this region, including the Passaic bedrock aquifer is naturally saline and not suitable for water supply wells.

Groundwater quality meets the definition of Class III-B. Furthermore, no community public water supply wells exist within a two mile radius of the site.

9.4.2 Surface Water Bodies

Tidal marsh formerly covered the entire area in which the LCP site is now located. Nearly all developed land in the Tremley Point area, inclusive of the LCP site, constitutes man-emplaced fill material laid over the former tidal marsh.

The LCP site is almost entirely surrounded by tidal water bodies. Most prominent among these is the Arthur Kill, which is a large tidal straight that connects Newark Bay and Kill van Kull to the north and Raritan Bay to the south. Other nearby tidal rivers and streams include the Rahway River, Piles Creek, and Marshes Creek.

South Branch Creek, the only water body located on the LCP site, is a man-made tidal ditch originating in the central portion of the Site and flowing east over 1,200 feet before discharging into the Arthur Kill. Four (4) different alignments of what have been referred to as South Branch Creek are documented. The current man-made channel was constructed around 1971 and discharges to the Arthur Kill approximately 950 feet south of the former "natural" South Branch Creek channel. The natural eastern South Branch Creek channel was subsequently filled in.

Two drainage channels, the Northern and Southern Off-Site Ditches, are located directly south of the LCP site in an alignment parallel with the LCP property line. The alignment of the two ditches has remained the same from prior to development of the LCP site to the present, with the exception of the culverts at the downstream ends of both ditches. The two ditches were redirected through the culverts between 1947 and 1951.

Comment [PJT204]: Ditch Report

9.4.3 Ecological Setting

Wetlands

Areas of wetlands are located in a narrow band along the entire length of South Branch Creek. The wetland zones generally extend approximately 25 to 50 feet from either side of the channel and slightly west of the headwaters, west of the railroad tracks. The wetlands are designated as estuarine, intertidal, emergent, mesohaline, and irregularly flooded.

The NJDEP letter of interpretation states that the wetlands are of "intermediate resource value". However, the wetlands bordering South Branch Creek have been adversely impacted due to surrounding land use and the on-site habitat assessment found the wetlands to be highly degraded and of relatively low habitat quality.

South Branch Creek and the Arthur Kill are National Wetlands Inventory (NWI)-mapped wetlands. There are no State designated wetlands on the LCP site mapped by New Jersey.

Habitat Assessment

Three ecological communities are identified at the LCP site, including;

- Urban Vacant Lot, with structures (upland portion of site)
- Brackish Tidal Marsh (South Branch Creek)
- Successional Old Field (Closed RCRA Unit)

No endangered, threatened, or rare (ETR) species or significant ecological communities were identified at the site. The flora and fauna found include species typically found in heavily industrialized areas within intertidal marsh ecosystems. Vegetative species found at the site are very common to highly disturbed areas and possess no Federal or State protection. Six terrestrial mammals and two terrestrial reptile/amphibian species were observed although no aquatic mammals were observed.

South Branch Creek is a man-made ditch with associated wetlands located in the eastern portion of the LCP site. The ditch flows to the east, connecting directly to the Arthur Kill. The ditch banks are excavated into granular fill soil and are partially lined with rip rap. The sediment bed in South Branch Creek is variable, ranging from organic to clay and silt to gravelly sediment.

9.5 Contamination Nature and Extent

9.5.1 Soil Summary

Contaminants related to LCP site activities have directly impacted soil quality. In some cases, contaminated soil provides a historic and ongoing source of contamination to other media.

Soil impacts are primarily observed in the shallow anthropogenic fill soils. Natural soils that underlie the fill are impacted to a much lesser degree. Soil constituents that clearly originated from historic chlor-alkali site operations are mercury, polychlorinated naphthalenes (PCNs), hexachlorobenzene (HCB), and PCDFs. PCBs are also a site-related constituent due their potential presence in electrical equipment on the site.

Mercury in soil is relatively immobile and is primarily present in relatively insoluble forms including mercury sulfide and elemental mercury. Elemental mercury is visible in soil in and about the production buildings.

Other non site-related constituents are present due to the anthropogenic fill and/or as a result of regional background conditions include arsenic, lead, PCDDs (dioxins), PAHs, and BTEX. These are distributed site-wide. Chlorobenzenes may be present in the fill as a result of their use at the adjacent NOPCO and GAF sites. Arsenic in some sections of the site may also be due to its use at the adjacent GAF and DuPont sites.

Site related contaminants in soil have been horizontally delineated to the north and west where the LCP property abuts the LPH Site, which itself has been investigated and has received an NFA designation for soil contaminants (Section 2.1.2). Soil contaminants are bounded to the east by South Branch Creek. Contamination in fill material has not been delineated in the area located south of the Linde Hydrogen Plant, however, given the findings of the Off-Site Ditch Investigation have shown site related contaminants in the Northern Off-Site Ditch. It is reasonable to conclude shallow soil contamination in the vicinity of the Linde Hydrogen Plant is bounded to the south by the Northern Off-Site Ditch, particularly given the unimpacted condition of the Southern Off-Site Ditch. Site related contaminants have been vertically delineated as evidenced by data from the underlying Tidal Marsh Deposits and Glacial Till soils.

Comment [PJT205]: GC#3

9.5.2 Low Marsh Soil Summary

Low marsh soil represents areas of sediment that is deposited as a thin veneer over the anthropogenic fill in vegetated areas along the margin of South Branch Creek. The contaminant distribution in the Low marsh soils is similar to that observed in sediments, reflecting mercury as the only principal site-related contaminant.

9.5.3 Groundwater Quality Summary

Surface Water Quality Standards (SWQS) are utilized herein for comparison to bedrock groundwater quality as the bedrock water-bearing zone was formally reclassified as Class III-B due to its natural saline conditions. The SWQS are utilized, in the absence of a NJDEP-approved method for the development of alternate groundwater quality criteria, to be protective of surface water quality in South Branch Creek and the Arthur Kill as a result of discharging bedrock groundwater. The overburden groundwater quality

Comment [PJT206]: GC#2

data are compared to the Groundwater Quality Standards (GWQS) given that its classification remains as Class IIA.

~~Alternative groundwater quality criteria (AGWQC) are proposed and utilized herein as the groundwater meets the requirements for New Jersey Class III B due to its natural saline conditions. The AGWQC are proposed for both the overburden and bedrock water bearing zones to be protective of surface water quality as a result of discharging groundwater and potential risks to human health resulting from potential direct contact.~~

The source of groundwater contamination within the overburden water-bearing zone is the dissolution of various constituents from the site soils. Accordingly, mercury is the only site-related contaminant that is generally found in groundwater, albeit at low concentrations. The other site-related constituents, including PCBs, PCNs, HCB and PCDFs, are relatively insoluble and are not detected in groundwater.

Other detected groundwater constituents included arsenic and other metals and several VOCs and SVOCs which are not site related. The highest VOC/SVOC detections are attributed to historic off-site sources including the adjacent NOPCO site and the historic wastewater conveyance from the former GAF site. Mercury levels in overburden groundwater is either detected at low concentrations or is not detected, and is generally limited to areas of the site in which very high levels of mercury are observed in the soils.

Most groundwater constituents in bedrock are undetectable except in the northwest area of the site, upgradient of the LCP production area. Mercury, benzene, and chlorobenzenes are detected within the zone in which the GAF groundwater extraction system has been shown to induce bedrock groundwater flow from the neighboring GAF site onto the LCP site. However, bedrock groundwater from this area is captured and treated by the adjacent GAF groundwater remediation system.

No free phase organic liquids were observed in the groundwater column in either overburden or bedrock monitoring wells.

Site-related contaminants and arsenic in groundwater have been vertically and horizontally delineated in both the overburden and bedrock water bearing zones. Delineation of non-site related contaminants benzene and chlorobenzene in the overburden groundwater is not complete in the southeast direction, towards the NOPCO facility. No further delineation is necessary of site related contamination in groundwater.

Comment [PJT207]: GC#3

9.5.4 Sediment and Surface Water Quality Summary

South Branch Creek and the Northern Off-Site Ditch exist within the highly contaminated Newark Bay and Arthur Kill system and has also been impacted locally by localized historical inputs in addition to the LCP site. Contamination in South Branch Creek and the Northern Off-Site Ditch is attributable to four general sources:

Comment [PJT208]: Ditch Report

Comment [PJT209]: Ditch Report

- LCP site operations,
- Contamination on site due to contaminated soil/anthropogenic fill,
- Discharges from non-site sources, and
- Regional contamination.

Mercury present throughout South Branch Creek and the Northern Off-Site Ditch sediment and surface water is clearly related to site sources through historic direct discharges and historic surface run-off. Mercury is suspended in surface water and not detected in soluble form (in filtered surface water). Sediment movement in South Branch Creek is the largest single transport mechanism from the site. The magnitude of this mechanism was substantially diminished after cessation of site manufacturing activities. Mercury concentrations are highest in the areas of historical inputs:

Comment [PJT210]: Ditch Report

Comment [PJT211]: Ditch Report

- The upstream area which has received drainage from multiple sources over the years, and
- Near the former City of Linden sewer pipe.

Mercury concentrations in South Branch Creek sediment attenuate with distance from the production area of the site and are comparable to regional Arthur Kill background at the confluence with the Arthur Kill.

Comment [PJT212]: Ditch Report

Mercury concentrations in sediments found in the Northern Off-Site Ditch indicate a historic pattern or runoff laterally from the LCP Site to the ditch. The mercury concentrations found, while lower than those found in South Branch Creek, are significantly elevated above Arthur Kill sediment and indicate historic input from the LCP Site. Mercury concentrations in the Southern Off-Site Ditch are lower than those found in the Arthur Kill and indicate that LCP related contaminants have not impacted the Southern Ditch.

Comment [PJT213]: Ditch Report

Other site-related constituents reported in sediments are low-level PCBs, PCDFs, and chlorinated benzenes, each of which decrease to background or undetected concentrations at the Arthur Kill. Arsenic concentrations in sediment, low marsh soil, and surface water are markedly elevated in the upstream area. Arsenic is likely present due to non-site sources (historic drainage along the railroad tracks from other sites including possibly GAF or duPont). Arsenic impacts also attenuate with distance along South Branch Creek, reflecting the generally low sediment mobility in the ditch. Other contaminants (metals, PAHs, and PCDDs) show minimal relationship to the site and appear to be of regional origin.

Arsenic concentrations in the Northern Off-Site Ditch indicate there has been a historic discharge into the ditch from adjacent operations at either the LCP or GAF sites or from fill placed in the area.

Comment [PJT214]: Ditch Report

Site related contaminants in South Branch Creek have been delineated to levels consistent with regional sediment contaminant conditions in the Arthur Kill. Given the fact that the sediment investigation included the full extent of South Branch Creek, no further delineation of sediment contamination is necessary.

Comment [PJT215]: GC#3

The investigation of sediments in the Northern Off-Site Ditch has not yielded complete delineation of Site Related contaminants in the upstream direction. It is recommended that further delineation sampling, as necessary, would be conducted as a part of a remedial pre-design investigation (PDI). The downstream end of the Northern Off-Site Ditch is believed to be connected via a culvert to South Branch Creek. Further delineation in the downstream direction, toward South Branch Creek, is not necessary.

Investigation of the Southern Off-Site Ditch has shown that it has not been impacted by LCP Site related contaminants. No further delineation of the Southern Off-Site Ditch is necessary.

Investigation of both South Branch Creek and the Northern and Southern Off-Site Ditches has shown that the presence of contaminants in Surface Water is driven primarily by suspended particles in the water column. Due to the dynamic nature of the medium and the tidal fluctuations, meaningful delineation of contaminants in surface water is not possible.

9.6 Risk Assessment Summary

~~Human exposures to Site media are currently limited since the Site is unoccupied and access is restricted by perimeter fencing. Hazard indices (HIs) for future Site workers (i.e., commercial/industrial, site specific, and construction) exposed to soil at the Site exceed the USEPA benchmark, indicating the potential for non cancer effects; exposure to elemental mercury via inhalation and inorganic mercury via ingestion made the most significant contribution to total HI. Areas impacted by visible elemental mercury are assumed to present unacceptable exposures. Dermal exposure to furans in groundwater also generated an HI above the USEPA benchmark for construction workers. Hypothetical future building~~

~~occupants exposed to vapor in indoor air have the potential for non-cancer effects, primarily due to mercury. Cancer risks for future Site workers were determined to be within the USEPA acceptable risk range. Cancer and non-cancer risks to current/future trespassers exposed to sediment in South Branch Creek were also with the USEPA acceptable risk range.~~

~~Several contaminants in South Branch Creek sediment have the potential to result in adverse ecological effects to benthic macroinvertebrates. Potential ecological risks were also identified for mammalian insectivores utilizing the terrestrial portion of the Site. However, ecological exposure to terrestrial soil is not considered a significant pathway given the limited habitat. Potential ecological risks for upper trophic level receptors feeding in South Branch Creek were in the borderline acceptable range.~~

The Human Health Risk Assessment (HHRA) indicated that exposure to soil and soil vapor by future commercial/industrial workers, site-specific workers, and construction/utility workers may result in adverse non-cancer effects; exposure to soil by future commercial/industrial workers may also result in adverse cancer effects. Dermal contact with groundwater by construction/utility workers has the potential to result in adverse non-cancer effects. Potential non-cancer hazards in soil and soil vapor were driven by mercury; potential non-cancer hazards in groundwater were driven by furans and manganese. No unacceptable cancer or non-cancer risks were identified for current/future trespassers exposed to sediment/bank soil in South Branch Creek. Hypothetical use of groundwater for potable purposes was also evaluated to support remedial decision-making and risk management; the HHRA indicated future potable use of groundwater by commercial/industrial workers may result in adverse cancer and non-cancer effects.

The Baseline Ecological Risk Assessment (BERA) indicated that contaminants in South Branch Creek sediment, primarily arsenic, barium, and mercury, have the potential to result in adverse ecological effects to benthic macroinvertebrates and sediment-probing birds. Potential ecological risks were also identified for terrestrial mammals (insectivores) and birds (invertivores and, to a lesser extent, carnivores) potentially exposed to contaminants in upland soil, driven primarily by mercury and hexachlorobenzene. However, the former facility offers limited ecological habitat for these receptors as the majority of the Site is paved or occupied by structures.

9.7 Conceptual Site Model (CSM) Summary

The LCP site and South Branch Creek are impacted with multiple contaminants; many are due to the presence of ~~historic~~ anthropogenic fill and the heavily industrialized area and not to site activities.

Comment [PJT216]: ES#1

- Soil is heavily contaminated, primarily with mercury which has had limited impact on dissolved (mobile) groundwater.
- Contamination in groundwater shows minimal migration either horizontally or laterally and is not moving off site ~~to any significant extent.~~ . It should be noted that the groundwater extraction system at the GAF site causes bedrock groundwater under pumping conditions to sweep through the western portion of the LCP site from the GAF site and then back to the GAF site to be captured by the extraction system.

Comment [PJT217]: SC#64

- Sediments and low marsh soils in SBC are contaminated with mercury and other constituents, especially in the near-facility areas, but the contamination decreases with distance from the site and is essentially background where SBC meets the Arthur Kill.
- Sediments in the Northern Off-Site Ditch are contaminated with mercury and other constituents. There is no apparent spatial pattern or gradient to the concentrations due to the entire length of the study area running adjacent to LCP Site operation areas.

Comment [PJT218]: Ditch Report

- Sediment contamination is due to historic inputs and not to ongoing sources.

- Biological specimens (fish and crabs) collected in South Branch Creek contain markedly elevated concentrations of mercury and other constituents compared with those collected in a nearby area.

9.8 Remedial Action Objectives (RAOs) Recommendations

Based on the RI analysis, the following Remedial Action Objectives (RAOs) are offered:

~~**Upland Areas (Manufacturing Facility)**~~

- ~~Prevent exposure to humans and wildlife from contaminated surface soils.~~
- ~~Prevent exposure to humans from contaminated soil and shallow groundwater in the subsurface during future construction activities.~~
- ~~Prevent contamination of indoor air in any future occupied structures from mercury vapor and/or VOCs.~~

~~**South Branch Creek**~~

- ~~Minimize uptake of mercury and other contaminants by biota from surface water and sediment.~~
- ~~Eliminate the transport of contaminated sediment from South Branch Creek to the Arthur Kill.~~
- Prevent or minimize potential current and future human and wildlife exposures – including ingestion and dermal contact with soils and groundwater – that present a significant risk whether from operations-related or non-site-operations-related constituents.
- Minimize migration of contaminated groundwater, and to the extent practicable, remediate to applicable standards.
- Remediate sediment in South Branch Creek, the Northern Off-Site Ditch, and associated Wetlands to levels protective of biota.
- Prevent human exposure to contaminated building materials and physical hazards that may results in potentially unacceptable risk.

Comment [PJT219]: Final FS Report

Section 10

References

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C-2 – Previous Investigations

Appendix C-1: RI Field Investigation

Appendix C-2: Previous Investigations

Appendix D: Hydrogeologic Data

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Appendix D-1: Hydraulic Conductivity Reports

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Appendix E: Wetland Delineation

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Appendix G: Representative Photographic Logs

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							Response approved – no further review required	EPA and IES appear in agreement – EPA to confirm	Further EPA review/ concurrence requested
Gen. Comment 1	2	Statements about off-site sources not well supported	Modified text	OK	OK		X		
Gen. Comment 2	3	Evaluate groundwater as Class IIA unless formally reclassified by NJDEP	Groundwater reclassification petition for bedrock approved; overburden petition will be retracted and overburden concentrations will be evaluated as Class IIA	OK if NJDEP approves Alternate Groundwater Quality Criteria (AGWQC) for bedrock	NJDEP will not accept AGWQC so there will be no ARARs for bedrock groundwater	It has been agreed that the NJ Surface Water Quality Standards (Saline) will used as default ARARs until a method to calculate the AGWQC has been developed		Resolved for overburden. NJ Surface Water standards will act as ARARs until method to develop AGWQC is developed.	
Gen. Comment 3	4	State whether delineation in specified medium is complete	Text example presented	OK but include groundwater data and ditch will need investigation	Additional information on off-site groundwater quality presented.	The ditch investigation was conducted in August 2011, the DRIR edits pertaining to the ditch results were provided in December 2011.			
Gen. Comment 4	5	State that RI will only address contamination as far as the Arthur Kill (Transect G)	Text insert presented	OK with one minor wording change	OK (but whether agencies pursue additional investigation not within IES control)		X		
ES Comment 1	5	Site does not meet definition of historic fill	IES disagreed and requested discussion.	Revise response pursuant to 4/29/09 call	IES will eliminate the term "historic fill" from the RIR in interest of project progress but does not agree with NJDEP interpretation and reserves the right to pursue the issue in the future		X		
ES Comment 2	6	Requested language changes (including regarding historic fill)	Text inserts presented except historic fill	Revise historic fill response pursuant to 4/29/09 call	See above RE historic fill; no comments on other responses	Further language clarification provided that "secondary" COCs are colocated with mercury and exceed standards less frequently and to a lesser magnitude.		Confirm other responses OK	
ES Comment 4[1]	7	Minor edit	Revised text presented	Request additional change.	OK		X		
ES Comment 5	7	Minor edit	IES disagreed – retain language	OK			X		
ES Comment 6	7	Minor edit	Revised text in accordance with General Comment No. 2.	OK			X		
ES Comment 7	7	Minor edit	Revised text presented along with reference to revised Section 7	OK			X		
ES Comment 8	8	Remove sentence referring to regional data	Revised text presented	OK			X		
ES Comment 9	8	Minor Edit	Text is accurate, recommend no change	Suggest removing whole sentence	OK		X		
2	9	Correct typo	Correction will be made	OK			X		
3	9	Specify wastewater treatment location	Text inserts presented	OK			X		
4	10	Unclear whether unnamed ditch was sampled	Was not but should not affect remedy	Needs to be sampled	See Gen. Comment 3		X		
5	10	Delete reference to non-potability of groundwater	Have original language remain and provide additional language.	OK			X		
6	13	Mention Pralls Island wetlands	Text insert and revised figure presented	OK			X		
7	13	State all sample analytes	Text insert presented	OK			X		

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							Response approved – no further review required	EPA and IES appear in agreement – EPA to confirm	Further EPA review/ concurrence requested
8	13	State number of borings	Text insert presented	OK			X		
9	14	State whether delineation is complete	See response to General Comment 3	OK			X		
10	14	Confusing language regarding salinity	Revised text presented	OK			X		
11	14	Inconsistency on fill thickness	Revised text presented	OK			X		
12	15	Inconsistency on aquitard thickness	Revised text presented	OK			X		
13	15	Describe GAF groundwater extraction system	Text inserts presented	Add details on containment wall.	Insert provided.			ü EPA needs to approve revision	
14	17	Tidal influence in bedrock unclear		OK but add contour map for high and low tide	Data not available for these maps; clarifying language presented	Request final approval of edit rom EPA		ü EPA needs to approve revision	
15	18	State that extraction system capture is unclear	Text inserts presented to confirm sufficient evidence	EPA does not fully agree	Additional inserts presented	Request final approval of edit rom EPA			EPA needs to approve revisions
16	21	Arthur Kill flow direction varies	Revised text presented	OK			X		
17	22	Need to screen against impact to groundwater values	Not relevant since groundwater was analyzed	Still need to use them	Will add these screening levels; revised text presented	Reiterate 2010 Response as appropriate.		ü EPA needs to approve revision	
18	23	Add sections on COCs and screening criteria	Already presented in sections so not needed	OK			X		
19	23	Inconsistency on mercury migration description	Revised text presented	Ok	OK		X		
20	24	Clarify speciation discussion	Revised text presented	OK	Additional correction		X		
21	25	Clarify TCLP discussion	Clarification on hazardous waste status provided; Section 7 will address	OK but needs to verify no listed hazardous waste other than the closed RCRA unit	Per 8/13/109 conference call response is acceptable		X		
22	26	Acknowledge additional mercury transport mechanisms	Text insert presented	OK			X		
23	26	Acknowledge additional mercury transport mechanisms	Text insert presented	OK			X		
24	*27*	*Need justification for off-site sources of arsenic*	*Text insert presented*	*Insert is OK but unconvinced no arsenic sources and should stay as COPC in the human health risk assessment*	*Arsenic was a COPC in the HHRA*			*ü EPA needs to confirm no additional language required*	
25	28	Relevance of TSCA PCB standard questioned	NJNRSRS is presented in report and TSCA standard for reference only	OK			X		
26	28	Discuss barium	Text insert presented	OK with minor revision	OK		X		
27	29	Clarify TCDD as 2,3,7,8 isomer	Revised text presented	OK			X		
28	29	Clarify and expand CDD/CDF discussion	Text insert presented	EPA unconvinced that CDDs/CDFs are regional[2]	8/25/09 memorandum submitted expanding on the issue; CDDs not associated with chlor alkali facilities	EPA Agrees.			Consensus on language required
29	30	Add vapor screening level for Hg	Text insert presented and will be added to Table	OK			X		
30	31	List VOCs over vapor screening levels	Text insert presented	OK			X		

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							Response approved – no further review required	EPA and IES appear in agreement – EPA to confirm	Further EPA review/ concurrence requested
31	31	Indicate precedent for AGWQC	They have been but methodology no longer acceptable to NJDEP; see General Comment 2	OK			X		
32	31	AGWQC need to be protective	See General Comment 2	OK			X		
33	32	Justify off-site bedrock groundwater source	Text added in response to General Comment 15	OK			X		
34	32	Are filtered and unfiltered lab results mixed up?	No evidence they were	OK			X		
35	32	Correct arsenic contradiction	Revised text presented	OK			X		
36	32	VOCs could be site related	Revised text presented	Additional info would be required to prove off-site origin	Comment noted along with confirmation that VOCs were included in the HHRA and Ecological Risk Assessment (ERA)	EPA Agrees.			Consensus on language required
37	33	Provide turbidity in CDD/CDF groundwater sample	Text insert presented	Delete “likely” and replace with “may be”	OK		X		
38	34	Delete sentence	Was provided for perspective	Still confused	Will delete		X		
39	34	Include human health-based surface water standards	Will be added to relevant tables but per EPA no fish consumption pathway in HHRA	EPA will be requesting information on that pathway in the HHRA[1]	No consumable fish in SBC. Column added to table(s).	EPA Agrees.		X	Consensus on language required
40	35	Revise Hg methylation statements	Revised text presented	Small amounts of methylation can be important and cannot dismiss methyl Hg as a COPC[1]	Was included in the risk assessments	EPA Agrees.		EPA needs to confirm no additional language required	Consensus on language required
41	36	Clarify use of ”human refusal” to determine sediment depth	Additional explanation presented	OK			X		
42	36	Add information on off-site arsenic sources	Text insert presented	OK			X		
43	37	Justify conclusion of no PCB problem in South Branch Creek	Recommend no additional discussion	Based on PCB concentrations, more discussion required[i]	Revised text presented	Final text edited.			EPA needs to approve revisions
44	38	Clarify AVS/metals bioavailability statements	Text insert presented	Other factors also control bioavailability	Additional text insert presented	EPA Agrees.			Consensus on language required
45	39	Clarify whether biota are consumed whole	Text insert presented	OK			X		
46	40	Wrong word	Correction will be made	OK			X		
47	40	Arsenic comment is speculative	Text insert presented	Ok with minor deletion[3]	OK		X		
48	41	Clarify explanation for observed BSAFs	Revised text presented	OK			X		
49	43	Include barium	Revised text presented (see General Comment 48)	OK			X		
50	44	Arsenic/historic fill inconsistency	IES disagreed	Revise per 4/29/09 call	See Response to Executive Summary Comment 1	Provided revised section 6.9.1 text			Consensus on language required

Final Response to USEPA Comments
Comment Tracking Table
LCP Chemicals, Inc. Superfund Site
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							Response approved – no further review required	EPA and IES appear in agreement – EPA to confirm	Further EPA review/ concurrence requested
51	44	Add chlorobenzene language	Text insert presented	OK			X		
52	45	AGWQC are unacceptable	see General Comment 2	OK			X		
53	45	Support drainage statement	Text insert presented	Probably accurate			X		
54	45	Add site-specific component to transport discussions	Addressed in revised Section 7	OK			X		
55	46	Hg may be transformed to volatile forms	Revised Section 7	Elemental Hg indicates volatilization is an important pathway	IES acknowledged elemental Hg presence but data indicate pathway not significant	EPA Agrees.			Consensus on language required
56	46	Bacteria can methylate Hg	Revised Section 7	OK			X		
57	47	Present source of off-site Hg	Agreed – see revised Section 7 and response to Gen. Comment 15	OK			X		
58	47	Cite fish and crab data here	Agreed	OK			X		
59	47	Present source of off-site Hg	Agreed – see revised Section 7 and response to Gen. Comments 13 and 33	OK			X		
60	47	Acknowledge current potential for Hg transport to SBC	Most loading historical	OK if acknowledge most but not all	OK		X		
61	48	Small amounts of Hg suspended in surface water may be important	Text presented for Section 7	Text not revised per comment	New text presented	EPA Agrees.		X	Consensus on language required
62	48	Delete reference to interim action	OK to ,mention per 2/10/09 meeting; text insert presented	OK			X		
63	49	Include groundwater flow discussion and cross-sections	Discussion appears in Section 9.4; cross-sections not presented due to minimal migration	OK – see response to General Comment 64			X		
64	49	Statement regarding lack of off-site groundwater migration incorrect	Text insert presented	OK if remove "significant" and provide evidence of GAF well capture	OK		X		
65	50	Define surface soil depth and modify RAOs per FS meetings	OK	OK			X		
66	50	Table title is incorrect	Title is correct	OK			X		
67	51	Show contouring data	Revised Figure 5-2 with data attached	OK			X		
68	51	Elevation data discrepancy	Revised Figure 5-3 attached	OK			X		
69	51	Elevation data discrepancy	Revised Figure 5-4 attached	OK			X		
70	51	A'-A'- revisions requested	Revised cross section attached	OK			X		
71	51	Anomalies on contour map	Well MW-15S omitted due to anomalies; MW-8S ,matches (Figure 5-6)	OK			X		
72	52	Anomalies on contour map	Well MW-15S omitted due to anomalies	OK			X		
73	52	Anomalies on contour map	Well MW-15S omitted due to anomalies	OK			X		
74	52	Add GAF pumping wells	GAF pumping well DEW-4A has been included on Figure 5-11 (attached)	OK			X		
75	52	Clarify contour lines	Revised Figures 5-12 and 5-13 attached with clarifications	OK			X		

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76	53	Add isoconcentration contours on groundwater contaminant maps	Revised Figures 6-18a, 18c, 20a, 20c, 22a, 22b, 23a, and 23b attached	OK			X		
77	53	Include total mercury values and cross-references in Table 6-5	Revised Table 6-5 attached	OK			X		
78	53	Define acronyms in Table 6-15	Will be defined in final RIR	OK			X		
79	53	Unit error for percent solids	Will be corrected in final RIR	OK			X		
80	54	Table 6-17 missing	Table will be included	OK			X		

FS Comments	EPA Comment	BC Response
General Comment 2	Numerical PRGs for Sediment and Low Marsh need to be established.	To be completed in updated BERA
General Comment 5	Arsenic should be considered a site contaminant	Addressed in RI Specific Comments #2,50
Specific Comment 2	Revision to statement of histoic fill mapped by NJDEP	Addressed in RI ES Comment #1
Specific Comment 18	Remove statement of fill meeting historic fill definition	Addressed in RI ES Comment #1
Specific Comment 19	Provide Description of Free Product	Already addressed in Section 6.1.8 and 6.4.3 of the RI
Specific Comment 26	Sediment and low marsh soils must be compared to ecological criteria.	They are. No change necessary.
Specific Comment 27	Arsenic is site related based upon sediment result locations	Already addressed in Section 6.1.8 and 6.4.3 of the RI
Specific Comment 28	Remove statement of mercury attenuating to levels found in AK as you move away from site.	Statement is accurate, with support from regional data. This issue was not a concern during the RI reviews.
Specific Comment 29	Arsenic is site related based upon tissue data and sample locations	Addressed in RI Specific Comments #2,50

[1] There is no ES Comment 3.

[2] Some EPA comments interspersed with response text

[3] Some EPA comments interspersed with response text